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Meta-Analysis of Data from the Submarine Ventilation Doctrine Test Program

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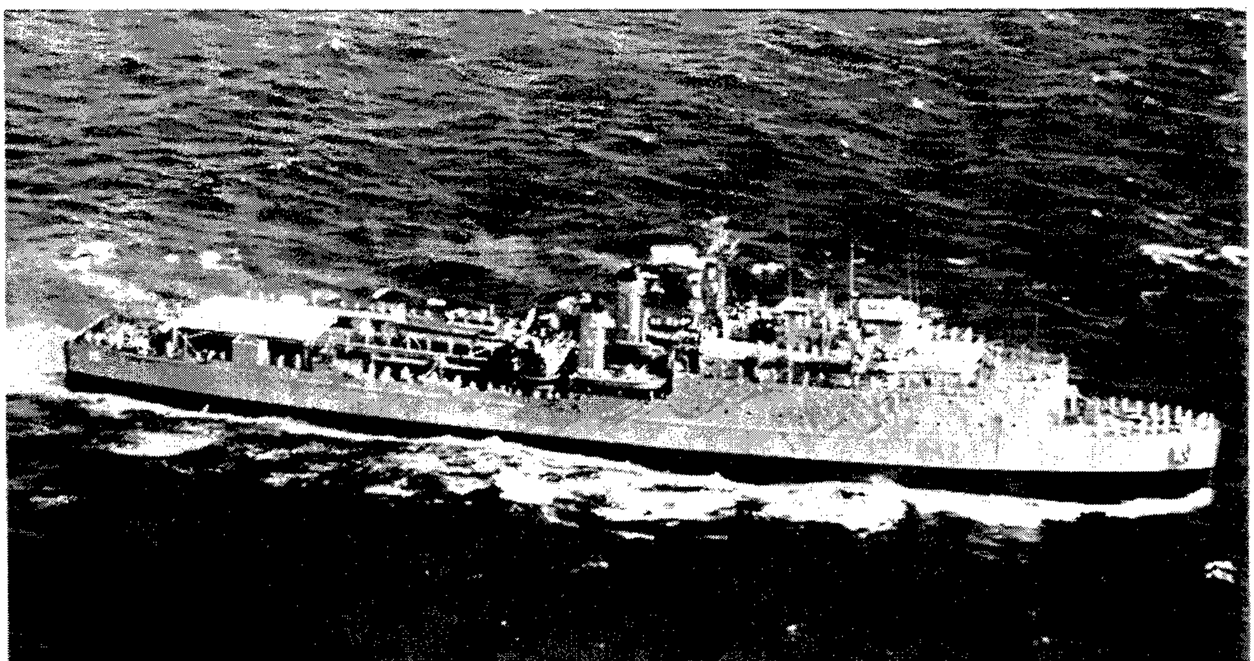

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Shipboard fires present a variety of novel problems for firefighters and, even by Navy standards, the space limitations and operational constraints of submarines present extreme cases. The Submarine Ventilation Doctrine Test Program was developed to address submarine-specific issues regarding the use of ventilation systems to control smoke and heat movement, maintain habitability in critical spaces or provide safe ingress/egress routes. This program sponsored six test series between January 1995 and August 1996 and made specific recommendations for the use of ventilation during submarine firefighting. Subsequently, questions were raised regarding whether this doctrine might cause the fire to grow beyond the size that would have been obtained in the absence of external ventilation or might inhibit damage control effects by increasing the smoke and heat load. In this report, data from all six tests were pooled and subjected to a meta-analysis. It was found that opening external hatches caused atmospheric conditions in the Control Room to deteriorate while improving conditions in the Laundry Room (fire compartment). Opening of the sail hatches tended to mitigate the effects of opening the Forward Escape Trunk; opening the Weapons Loading hatch had minimal additional effect.

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META-ANALYSIS OF DATA FROM THE SUBMARINE VENTILATION DOCTRINE TEST PROGRAM

1.0 INTRODUCTION

Due to the unique nature of the environment, shipboard fires present a variety of novel problems for firefighters. In particular, the enclosed spaces permit heat and smoke to build to levels far in excess of those found in most structural fires. Further aggravating the situation is the high rate of heat transfer through the steel bulkheads and decks, which contributes to rapid fire spread. Finally, fire fighting tactics are constrained by the necessity of maintaining habitability in close proximity to (and sometimes within) the area threatened by fire.

Even by Navy standards, the space limitations and operational constraints of submarines present extreme cases. For example, the necessities of noise reduction require that submarine decks be suspended from the interior of the ship's frame rather than being directly connected to the hull. As a consequence, there are channels between the deck edge and the hull which can act as chimneys in the event of a fire. Also, submarines typically have only two water tight compartments; within each of these, the individual compartments are separated by non-water tight joiner doors.

Fire fighting doctrine for surface ships is dictated by Naval Ship's Technical Manual (NSTM) Chapter 555. Historically, the submarine community has not had an equivalent standard[1], published fire fighting doctrine. Instead, the Atlantic and Pacific Fleet submarine Type Commanders promulgated guidelines for various classes of submarines. Typically, those guidelines were based on NSTM 555 doctrine, with modifications as needed to comply with the realities of submarine operations.

In general, the Type Commanders' guidelines for pierside submarine fire fighting called for the closure of topside hatches upon discovery of a fire, with reopening of the hatches at the discretion of the Commanding Officer. Isolation of the fire compartment is generally not feasible, since the joiner doors are neither water nor air tight. Surface ship doctrine for most fires (other than main space fires) is the opposite, calling for isolation of the affected compartment, but leaving closure of the topside hatches to the discretion of the Commanding Officer. In contrast, standard shore-based practice calls for prompt ventilation of the structure, usually by opening windows or breaching the roof.

The wide variation in recommended procedures, especially in regard to ventilation, is partially due to the differences in the circumstances and goals of the fire fighters. For example, in shore-based fires, the primary goal is usually to save lives, even if the structure is lost. In this context, rapidly venting smoke and heat expedites the search of people and is therefore beneficial. At sea, however, continuing the ship's mission may be a higher priority. Accordingly, isolation of the fire takes priority, even though the actions to accomplish that may contribute to increased levels of smoke and heat in the affected areas.

Clearly, it is highly desirable to minimize those adverse side effects while containing the fire as quickly as possible. Over the past two decades, the surface ship community has sponsored several test programs aimed at controlling the generation and movement of smoke and heat, via ventilation control, while preventing the spread of the fire. Two relatively recent examples of such work are the Smoke Ejection System (SES) [2] and the Internal Ship Conflagration Control (ISCC) [3] programs.

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[1] This is no longer the case. Recently, NSTM Chapter 555, Volume 2 [1] was adopted to standardize submarine fire fighting.

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During that period, however, there were no investigations of the applicability of surface ship experimental results to submarines. As a result, the submarine community has adopted some surface ship techniques and rejected others, based largely on intuitive extrapolations from one environment to the other. In particular, the advantages and disadvantages of securing or opening the topside hatches under different fire conditions were not understood. Similarly, the possible benefits of using the submarine's installed ventilation system to control smoke and heat movement, to maintain habitability in critical spaces or to provide safe ingress or egress passages were unknown.

In June 1994, the submarine community began to address these issues by drafting a proposed test plan [4] for an experimental program intended to verify or refute the intuitive expectations, using a variety of fire scenarios. This proposal evolved into the Submarine Ventilation Doctrine test program, which is described in references [4] - [7].

Under the umbrella of this program, six test series were conducted between January 1995 and August 1996. The results of these tests have been documented in five letter reports [8] - [12]. It was found that, for a variety of pierside fires, natural ventilation via some combination of the sail, forward weapons hatch and forward escape trunk hatch provided the best method of maintaining habitability in the Control Room.

Based on those results, the final test report [12] recommended that the draft submarine fire fighting ventilation doctrine [13] be adopted as written. This revised doctrine calls for opening the sail hatches and the forward escape trunk hatch during pierside fires. For most fires, this provides ventilation through the sail, with makeup air entering through the escape trunk. In the special case of a fire located directly below the escape trunk, the circulation is reversed, with venting from the escape trunk and suction through the sail. In either case, the result is that fresh air is continuously flushed through the Control Room, keeping it relatively clear. A further benefit is that a clear path for egress or reentry is maintained via the escape trunk (for most fires) or the sail (for escape trunk fires).

The benefits of this revised doctrine seem clear in regard to maintaining habitability of the Control Room and providing a safe egress path. However, further questions have subsequently been raised regarding whether this doctrine might:

1. cause the fire to grow beyond the size that would be attained in the absence of external ventilation; or

2. inhibit damage control operations by increasing the smoke and heat load.

The present report was intended to address these questions by pooling the data from all six test series and performing a more rigorous analysis using statistical techniques. The methodology used in this meta-analysis is discussed below. The primary goals of this analysis were:

1. to verify the effects of open versus closed external hatches on the habitability of the Control Room; and

2. to investigate the corresponding effects on the growth of the fire, as measured by temperature increase and concentrations of O_2 and CO_2.

2.0 TEST DESCRIPTION

All tests in the Submarine Ventilation Doctrine Test program were conducted aboard the ex-USS SHADWELL (LSD 15), located in Mobile, AL. For these tests, a portion of the port wing wall was reconfigured to approximate the forward section of a LOS ANGELES (SSN 688) class attack

submarine. The details of the modifications are provided in [4] - [11] and are summarized in Figure 1, which shows an isometric view of the test area as seen from the prospective of the well deck. The test area configuration used in the Submarine Ventilation Doctrine Tests was called SHADWELL/688 to distinguish it from configurations used in other large-scale fire tests conducted on ex-SHADWELL.

SHADWELL/688 was modified several times to incorporate suggestions from the Fleet regarding ways of increasing the realism of the tests. Figure 2 is a time line indicating the test periods and the times at which those modifications were made. Early in the test program, between test series 1 and 2, a partition was added to the Control Room to divide it into two compartments, a smaller Control Room and the Navigation Equipment room. A new door, D1', connecting these two compartments, was also added at that time. Shortly after the start of series 2, the Laundry Room was also divided by an "L" shaped partition containing another door, D7'. The area inside the new partition was subsequently known as the Laundry Room while the area outside the partition became a passageway (unnamed).

The third modification was the addition of an extension above the forward escape hatch (H3). This was added, during test series 3, to simulate the trunk which, on a real LOS ANGELES class submarine, extends from the mid-level to the outer hull. It was believed that the flow restriction produced by this chimney might affect the ventilation when the H3 was opened. Furthermore, it was suspected that the pressure difference between H2 and the original H3 (due to the difference in elevation) might have had an effect. Also added during series 3 was a vent to permit the AMR space to be exhausted to the outside.

As noted earlier, the acoustic isolation in a modern submarine requires that the decks be suspended from the frames instead of attached to the hull. To simulate these deck-to-deck connections, four holes were cut in the Control Room, Wardroom, Combat Systems and Crew Living decks. The Control Room and Wardroom alterations were made in the middle of series 3 while the changes to the other two compartments were postponed until after series 3 was completed.

The frame bay openings were themselves modified after the end of series 4 by the addition of ducts which directly coupled the holes in the Control Room and Wardroom decks. Likewise, the Combat Systems frame bay openings were connected to those in the Crew Living space. This had the effect of bypassing the mid-level compartments so that lower level fires could directly affect the upper level. It was believed that this arrangement was more realistic because, on submarines, the Wardroom and Crew Living compartments have false bulkheads that separate the frame bays from the actual compartments.

Finally, during series 5, an exhaust vent (similar to that previously installed in AMR) was added to the Fan Room and safety grates were placed over the frame bay openings in the Control Room and Combat Systems decks.

Instrumentation was installed throughout the ex-SHADWELL test area in accordance with the test plans [5] and [6]. Data were collected from all channels (typically, about 360) at one second intervals using two 200-channel analog-to-digital (A/D) converters installed in a MassComp computer. Custom software controlled the operations of both A/D converters, provided real-time scaling and display of the data and saved the data to disk in two binary files, one for each of the A/D units. These files were written to tape and archived for off-line analysis.

In general, the tests were considered to have concluded when conditions in the test area reached (approximately) a steady state. Often, data continued to be collected for some time after this point and, during this post-test period, firefighters and other test personnel sometimes entered the test area to extinguish the residual fire, collect samples or to make observations. These intrusions created artifacts, such as sudden dips in the curves. An example of this behavior is discussed in

Section 4.1. Accordingly, artifacts which occurred during the post-test phase were not considered in the analysis that follows.

3.0 META-ANALYSIS METHODOLOGY

3.1 Selection of Test Cases

Comparisons between tests in different series (and, sometimes, even within a series) were complicated by the many configuration changes over the course of the test program. This report attempts to circumvent these difficulties by performing a meta-analysis of all the available data. Meta-analysis provides methods for combining data from several tests to increase the statistical power of the analysis. In the case at hand, descriptions of all 108 tests were combined into one set. Considerable effort was directed toward extracting the best possible descriptions of the tests from the available documentation. This included a complete review of the original test logs and discussions with test personnel as well as reference to the test plans and test reports.

Based on this information, a Microsoft Excel™ spreadsheet (Appendix A) was created to document the state of each of the parameters that was varied during the entire test program. In all, 48 parameters were tracked in this spreadsheet, classified into the following seven broad categories:

1. test designation;
2. environmental factors;
3. fire description;
4. state of hatches;
5. state of doors;
6. test facility modifications; and
7. state of active ventilation.

The test designation consisted of the date and test number, which were used to identify the tests for future reference, and a code indicating the purpose of the burn (instrument calibration, demonstration and test). Ambient temperature, wind speed and wind direction were recorded as environmental factors. Fire location (compartment), type (pan or wood crib), fuel and fire size comprised the fire description category. Hatches and doors were noted as open, closed or variable (changed during the test run). In addition, door closures were further specified as water tight or joiner doors whenever that information was available. The use of smoke blankets was reported here since they could be considered as a type of closure.

As discussed above, the test facility was modified several times during the 15 months of actual testing. The presence or absence of these modifications was noted in the spreadsheet. Lastly, the state of the active ventilation system was recorded. This included factors such as the time that the recirculation system was secured, the settings of the induction and exhaust blowers and the use of smoke blankets. The latter information was included here, as well as in the section on hatches, because their deployment requires manual intervention and, therefore, they may be considered to also be an active ventilation control measure.

Once all of the test parameters had been recorded, the spreadsheet was read into a database program and progressively sorted to isolate specific cases. The database was used because it was found that the sort function built into Excel occasionally corrupted the spreadsheet. Figures 3A - 3C are tree diagrams which indicate how this sorting was conducted and the number of cases in each sort bin.

The calibration and demonstration burns were eliminated from consideration; the former because they used methanol fuel (which was not considered to be a realistic case) and the latter because the presence of firefighters and observers within the test area seriously compromised data collection.

From the burns representing actual tests, those in which the fire was located in the Laundry Room were selected for analysis. The relatively small number of fires in other compartments did not permit meaningful statistical analysis and, therefore, they were not included. The vast majority of the Laundry Room tests (73 out of 78) were diesel fuel pan fires and these were selected for further investigation. There was insufficient data to permit a useful analysis of the eight cases in which the Laundry Room or the Control Room (or both) had not been modified by the addition of internal partitions.

Of the 65 tests in which both the Laundry Room and the Control Room had been modified, approximately one third were conducted with all frame bays closed (tests carried out prior to the installation of frame bay openings were counted as being closed) and another third with all frame bays open. In the remaining cases, either the status of the frame bays was not adequately documented or some were open and others closed, making the test unrealistic and difficult to analyze. Framebay ducts, bypassing the midlevel compartments, were installed in about 80% of those cases in which all framebays were open. The presence or absence of ducts was, of course, irrelevant when the framebays themselves were closed.

For the case of frame bays closed, there were five subcategories based on the state of the internal doors. Thirteen cases were classified as unknown because there was insufficient information to completely specify the configuration. Two of the other subcategories were eliminated because there was not enough data to analyze - each of these had a single member. The remaining two classes, designated category A and B, had six and five cases, respectively, and were included in the analysis. In category A tests, the doors were all closed except for 3 (the Escape Tunnel access) and 7' (the Laundry Room partition door) while category B tests had all doors open.

The open frame bay tests were divided into five classes, including several cases that were undocumented and nine cases in which the door configuration was changed during the burn, making comparison with other tests problematical. Category C, consisting of only two cases, was included in the analysis, in spite of its small size, because it was directly comparable with category B. The majority of the well documented cases for which the door configurations were invariant fell into category D, with doors 3, 4 (between the Crew Mess and the Wardroom) and 7' open and all others closed.

Each of the categories A through D (Figure 3A) were further broken down according to the state of the internal hatches (H4 - H13 in Figure 1), external hatches (H01 and H1 - H3) and, finally, fire size. The test numbers are shown below the final sort level in Figures 3B and 3C. All but two of these configurations were represented by single tests. In each of the two exceptions, there were two tests. Tests 4_01 and 4_02 were replicates. Test 4_10 was a special case in that it replicated 4_03 for all parameters tracked in this study, but had a unique ventilation configuration (the dampers were closed prior to the test to prevent passive smoke migration through the ducts). As a result, this test could not be compared to any of the others and was, therefore, not considered furthers. Other than this, data from all tests in categories B - D were analyzed for this report. Unfortunately, data for the tests shown in category A were not available.

Data from the selected tests were read from the data tapes and translated from the datalogger's native binary format to a more accessible ASCII (text) format using a custom file translation utility written for the MassComp. The converted data files, along with files describing the channel assignments used during the tests, were then transferred to a desktop computer for analysis.

3.2 Analytical Approach

It should be noted that the analysis of these tests was complicated by the nature of the test program. In keeping with the sponsor's desires, the Submarine Ventilation Doctrine program was oriented toward practical fire protection engineering, rather than scientific goals. In particular, the program

attempted to reproduce the layout of an actual LOS ANGELES class submarine in order to simulate a variety of possible submarine fire scenarios. The test configuration was changed frequently in order to improve the fidelity of the mock-up and a large number of parameters were varied to simulate the widest possible range of scenarios.

As a result, there were few replicated tests and many cases in which two or more parameters were varied simultaneously, making it difficult to separate the effects of each parameter alone. Also, there were many cases in which data were lost (due to instrument failures or other problems) and the test could not be repeated because of time and budget constraints.

In order to address these issues, it was decided that a bottom-up, rather than a top-down, analysis would be performed. In other words, instead of collecting data to address specific, predetermined questions, we look at the available data and ask "What can we learn from this?"

This approach starts with individual tests, shown as leaf nodes in the tree diagram (Figure 3). At each level, tests are compared with other tests at the same level to determine whether any observable effect could be attributed to whatever parameter distinguished the cases. We work up the tree by repeating this procedure at successively higher levels.

The first parameter of interest was fire size. As seen in Table 1, there are two replicates (tests 4_01 and 4_02) of a small fire scenario in a closed boat (*i.e.*, with all external hatches closed). Results from those tests were combined to create a single, representative data set which was compared with the large fire case of test 4_03.

Two pairs of data sets, shown in Table 2, were used to investigate the effects of opening the bilge hatches, H8 - H14. Both pairs involved large fires in a closed boat with internal doors open but, in one pair (4_03 and 4_05), the framebays were closed while in the other (4_07 and 4_06), they were open. Thus, comparison of 4_03 with 4_07 and 4_05 with 4_06 reveals information regarding the effects of the framebays.

Finally, Table 3 shows five tests which differed only in the status of the exterior hatches, H01 and H1 - H3. Since H01, located at the top of the sail, and H1, at the bottom, were effectively ANDed together (*i.e.*, the access was open only if H01 and H1 were open), they have been combined into one "virtual hatch" variable, referred to as "Sail" in the Table.

Reading from left to right in Table 3, the first four cases show the boat being progressively opened - no hatches open, H3 open, H3 and Sail open and, finally, all three open. In the last case, the boat is back to two open hatches, this time H2 and H3 rather than H3 and Sail.

The discussions below regarding the observed effects of changing a parameter are primarily based on analysis of air temperature data. Due to the large number of thermocouples used in each test (typically, there were from 5 to 20 times more thermocouples than any other type of sensor), it was necessary to reduce the amount of data to a manageable level before attempting to interpret it.

It is well known that, during a fire, many compartments have thermoclines which effectively divide them into a hot upper zone and a cool lower zone. This suggests that the temperature measurements could be classified according to the zone within which the thermocouple was located and that zonal average temperatures could then be calculated. This method would require that a determination be made, on a second by second basis, as to which thermocouples were in which zone. Consideration was given to this approach but, given the inherent inaccuracies in estimating the location of the interface layer, it was decided that the immense amount of work involved could not be justified. Accordingly, the simpler approach of calculating a single mean temperature and standard deviation for each compartment was chosen.

Considerably less information regarding O_2, CO_2 and CO concentrations was available - for each of the two compartments under consideration, there were two of each type of gas sensor, with locations designated as "high" and "low" in the test documentation. These data were primarily used as a "sanity check" on the validity of hypotheses that were originally developed on the basis of the temperature data.

An initial, cursory examination of graphs of gas concentrations indicated that, in most tests, there were substantial differences between the high and low sensors. This was especially common in the Laundry Room and reflects the high degree of stratification that is normally found in the fire compartment. It was also seen, although less commonly, in the Control Room.

Due to the relatively small quantity of gas concentration data available, and because there was good reason to believe that the samples were typically representative of different populations, no attempt was made to calculate sample means or standard deviations, in most cases.

In some instances, temperature curves from different tests were compared using an objective, statistical test to determine whether the curves actually represented different parent population or could reasonably have come from the same population. Since sample means and standard deviations had already been calculated for each test, it was possible to compare them using Student's t-test for significance of differences between means [14].

Given that n_i, m_i, and s_i represent the number of samples, the sample mean, and the sample standard deviation of data set i, we may calculate an estimate of the pooled variance, s, as

$$s^2 = (n_1 - 1)s_1^2 + (n_2 - 1)s_2^2 \,/\, (n_1 + n_2 - 2) \qquad \text{Eqn. 1}$$

where $n_1 + n_2 - 2$ is the number of degrees of freedom of the pooled data set. The value of Student's t is then

$$t = (m_2 - m_1) \,/\, s\left[(1/n_1) + (1/n_2)\right]^{1/2} \qquad \text{Eqn. 2}$$

For a given number of degrees of freedom and a desired confidence level, critical values of t may be found in statistical tables. Cases in which the calculated t exceeds this threshold are considered to be statistically significant at the specified confidence.

Using this procedure, it was found that many of the tests showed statistically significant differences at the 95% confidence limit. By this test, even the Control Room temperatures in tests 4_01 and 4_02 (which were replicates of the same scenario) were significantly different for almost the entire duration of the test. In contrast, the Laundry Room temperatures were statistically different only during two relatively brief periods. Many cases were seen in which statistically significant differences were found between tests even though each curve lies within the other's one-standard deviation error bars, as was found in some cases.

If this behavior seems to be counter-intuitive, it is because most scientists are used to thinking in terms of the normal distribution, for which a difference of one standard deviation corresponds to a confidence limit of approximately 68%. The normal distribution is the proper one to use when comparing a single value with some hypothetical population. However, when comparing the means of two sets of values, the t-distribution must be used. This is a narrower distribution (because sample means tend to cluster more closely than do the individual samples) and, for the typical sample sizes seen in these tests, a difference of only 0.77 standard deviations is significant at the 95% level.

Graphs of the key variables discussed in this report are included as figures. For reference, graphs of all variables considered in this analysis (including some that are not specifically addressed in the text) have been collected together as Appendix B.

3.3 The STAT Data Analysis Tool

A data processing tool, the SHADWELL Test Analysis Tool (STAT), has been written to aid in the analysis. This program is in the form of a plug-in module for Excel and may be used on any computer running Excel version 5 or later. STAT will be described more fully in a separate report [15] and is only briefly discussed here.

STAT was written with the assumption that input files would be in the standard format generated by the MassComp's binary-to-ASCII file translation utility (data channels in fixed-width columns; one time-step per row; time, formatted as hh:mm:ss, in column one).

Prior to creating an Excel workbook, STAT requires that the user enter a description of the experiment. This must include a title, test date, series number, test number, ignition time and the ASCII file containing the raw data. Of these parameters, only the ignition time and file path are critical; the remaining fields can be filled in with any information that is meaningful to the user. Ignition time must be accurate because this is used to convert from the MassComp clock time (24-hour time in hh:mm:ss format) to elapsed time in seconds. Once the base file has been imported, STAT provides a means to append additional channels from other files. This is necessary because, as mentioned previously, each of the MassComp's two D/A systems generates a separate file containing up to 200 channels. STAT is capable of handling an arbitrary number of files, limited by the amount of memory available. For the Submarine Ventilation Doctrine tests, two data files were sufficient.

Before any data analysis may be carried out, the user must set up a configuration for each channel of interest. Initially, a series of dialog boxes is used to create lists of test compartments, instrument types and physical units used by those instruments. Data channels are then described by selecting the compartment, instrument type and physical units from menus, which reduces the chances of making errors during data entry. Optionally, additional information regarding the exact location of the instrument within the compartment may also be entered.

The process of creating a complete channel configuration is somewhat time consuming but, once entered, the entire configuration may be exported (as an ASCII file) for reuse by another STAT file or for use in other programs. The dialog box format for specifying configuration information also permits editing of previous files when only a few channels have changed.

The compartment, sensor and units lists used in this analysis are presented in Table 4. Table 5 is an example of a typical channel configuration. A complete channel configuration includes one record for each of the approximately 325 channels used in a test. Only a fraction of those sensors was needed in this analysis so, for simplicity, the irrelevant records have been deleted from this table. Because there were two D/A systems in the MassComp, each of the 200 available channel numbers was used twice. To distinguish between them, an extra digit has been appended to each channel. Thus, n.1 represents channel n in the first datalogger while n.2 indicates the same channel in the second datalogger. Appendix C includes the complete channel configurations for all test series included in this analysis.

After raw data have been loaded into the Excel workbook and the channel configuration has been entered, the user may select specific data, based on the compartment and type of instrument, for further analysis. For example, it is possible to choose all instruments of a particular type, all instruments in a given compartment or instruments of a specific type located in a selected

compartment. To protect the integrity of the original data, selected data are copied to another page in the workbook before any data-altering functions are permitted.

Selected data may be filtered to identify suspect points. The filter command performs a sliding window average and flags (but does not alter) all points that exceed a user-specified threshold deviation (expressed in standard deviations) from that average. The normalization, smoothing and statistical analysis functions described below each provide an option to exclude data that was flagged by the filter. Also, the filter flags may be cleared, if desired, so that the user may start over with different filter parameters.

Data may be normalized to correct for systematic differences among nominally identical sensors or to adjust the sensor outputs to a known value. This is accomplished by averaging all of the pre-ignition data from a sensor (on the assumption that conditions in a compartment tend to be relatively constant during the period prior to ignition) and calculating the offset between this mean and the target value (either the mean value for the entire compartment or a user-specified value). That offset is then applied to all data from that sensor for the duration of the test.

It is also possible to smooth data using a sliding window. This is similar to the filter command, except that the smoothing routine replaces each value by the mean of all values within the window. This is done in two passes, calculation and replacement, to ensure that all means are based only on the original values and not on a mixture of replaced and original values.

Finally, if there are duplicate sensors within a compartment, data from them can be statistically processed to yield compartment means and standard deviations as a function of time. By comparing these values for various different tests, it is possible to estimate both the differences, if any, between the tests and the statistical significance of those differences.

4.0 ANALYSIS AND DISCUSSION OF TEST DATA

As was mentioned in the Introduction, the purposes of this work were to investigate habitability in the Control Room and fire growth effects in the fire compartment (Laundry Room). Important factors for habitability are air temperature, oxygen availability and toxic gas concentration, so data from the selected tests were sorted by compartment and sensor type to isolate Control Room temperature, O_2, and CO_2 concentrations. Laundry Room temperature was used as a measure of the fire intensity.

4.1 Development of Standard Procedures

Once the data were sorted, the initial phase of the analysis concentrated on Control Room and Laundry Room temperatures. Tests 4_01, 4_02 and 4_03 were the first to be processed, primarily because they represented scenarios in which the differences between large and small fires (0.68 m and 1.05 m diameter, respectively) could be directly compared. Also, 4_01 and 4_02 were the only replicated experiments and, therefore, were expected to give an indication of the amount of inter-test variability.

Procedures for analyzing the temperature data were developed by experimenting with the data set from Test 4_01 and were then used for the other tests. Various filter parameters were tried and it was found that at large values of the filter criteria (very high confidence levels), many extreme points were not filtered, even though they were clearly due to instrumental noise - temperatures corresponding to open or short circuited thermocouples, for example. A criterion of 1.7 standard deviations (approximately the 90% confidence level), applied to a five-point window, gave good results and was adopted as the standard method.

Temperatures which passed the above test were then normalized to the compartment's pre-ignition mean temperature. This step corrected for differences in sensor calibrations by adjusting the offsets of the individual thermocouples so that they produced the same nominal readings during the (presumed) steady-state period prior to ignition. The alternative of normalizing to a fixed temperature was rejected because the actual pre-ignition ambient temperatures of the compartments was not known.

The filtered, normalized data were then combined to produce compartment mean temperature values and standard deviations for each time interval. These outputs were then transferred to a plotting program for generation of the graphs. The data were found to be rather noisy, so a five-point smoothing function was applied and the compartment pre-ignition mean temperature was subtracted to convert from absolute temperature to temperature difference. Since the actual baseline temperatures varied considerably from one test to the next, this correction made comparisons between tests easier by setting all of the curves to the same initial conditions.

The first thing that was noted was the presence of a gap in the data prior to about +200 seconds (elapsed time) as seen in Figure 4. The same discontinuity was also seen in data from the Control Room and in data from other types of sensors. Further inspection revealed that there was a real gap in the time track for this test, with the clock jumping from 13:07:21 (+89 seconds) to 13:10:01 (+249 seconds) in one step. Furthermore, this anomaly was present in the outputs from both dataloggers. Two possible explanations were considered:

1. The MassComp system clock actually skipped forward 159 seconds for some unknown reason; or
2. the datalogger stopped accepting data for a period of 159 seconds and then resumed operation.

If the former were the case, we would expect both the values and the slopes to be continuous across the gap whereas, in the latter case, there would be a significant difference in the value and, most likely, in the slope as well. As shown by the lines superimposed on the graph in Figure 4A, the slopes are indeed the same before and after the gap and the values are reasonably close - certainly within the variance seen elsewhere in the plot. Based on this evidence, the data gap was attributed to a clock glitch that caused the data for +90 seconds to be logged as having occurred at +249 seconds.

With this hypothesis, the time track for Test 4_01 was adjusted by subtracting 159 seconds from the elapsed times, starting at +249 seconds. This has the effect of moving most of the points horizontally to the left, as shown in Figure 4B. As another check, Laundry Room air temperature data from Test 4_02, which was a duplicate of Test 4_01, are also included in Figure 4B. There is very good agreement between the two curves, which supports the hypothesis. No other instances of this type of artifact have been found in any other data set. In the following discussion, Test 4_01 always refers to the time-corrected data set, unless specified otherwise.

As a result of this experience, it became standard procedure to plot the flame temperature thermocouple data for every test prior to proceeding with the analysis. In addition to making it easy to detect data gaps, this also provided a quick verification that the ignition time, entered when the data set was created, was correct.

The other noticeable feature seen in plots from Test 4_01 is the sudden temperature drop in the vicinity of +1700 seconds. According to the test logs, two people were in the test area collecting gas samples during this run so it is likely that this anomaly was caused by their presence.

Many of the tests were found to exhibit qualitatively different behavior at high values of elapsed time. This was thought to be primarily due to variations in the original fuel load, which caused

fires to burn out at different elapsed times, and to human intervention, similar to that noted above, at various times in some tests.

It was found that, in the five tests used to evaluate the effects of various hatch openings (see Table 3), the upper and lower Control Room O_2 concentrations were virtually identical. Likewise, the two CO_2 sensors in the Control Room were also indistinguishable. Accordingly, these data were averaged and smoothed using the same procedures that were developed for temperature data. For these same tests, the Laundry Room gas concentrations indicated significant stratification and were not averaged. They were, however, smoothed using the same five-point smoothing function that was applied to the temperature data.

4.2 Reproducibility of Replicate Tests

As was mentioned previously, Tests 4_01 and 4_02 were compared with a t-test to provide an objective criterion for determining whether they were, or were not, statistically different. In Figure 5 the bold, horizontal lines indicate periods during which the critical t (95% confidence level) was exceeded, indicating that the two tests were actually different. As is evident, the two tests are different for the Control Room but, with the exception of relatively brief periods, not for the Laundry Room.

The primary reason for this distinction is that, in the Laundry Room conditions are very dynamic, both spatially and temporally, leading to very large standard deviations. The only times during which a significant difference was found were brief intervals during the pre-ignition period, when the compartment was quiescent and the errors are very small, and the period during which people inside the test area caused a disturbance.

This also illustrates the fact that deviations too small to be considered significant in the fire compartment can translate into significant differences in places remote from the fire. Actually, it is not that the original differences are being amplified but rather that the background noise is being attenuated so that small differences become detectable.

The inter-test variability that is revealed by the t-test is attributed to the combination of experimental variablility and the presence of uncontrollable factors, such as variable environmental conditions during different tests.

Collectively, these effects can make even nominally identical tests different in a rigorous, statistical sense. From an engineering standpoint, however, the real question is: Does the observed difference make a difference? In the present case, it makes more sense to visually compare curves with the goal of estimating what impact the observed differences might have on habitability and fire fighting. This becomes even more important when there actually are purposeful differences between test scenarios. In that case, it is virtually assured that the statistics will show a real, provable difference, but it may not make any practical difference.

As stated previously, the results of 4_01 and 4_02 were combined to form a composite data set representative of this small fire, closed boat scenario and this set was then used for further comparisons with results from other scenarios. In the following discussions, the merged set, shown in Figure 6, is referred to as Test 4_01/02.

4.3 Effects of Fire Size

The effect of fire size was evaluated by comparison of Test 4_01/02 with 4_03, as indicated in Table 1, and these results are shown in Figure 7.

The Control Room temperatures continue to increase for the duration of the test, never reaching equilibrium, and the rate of rise for the large-fire case is more than two times greater than for the small fire.

In the Laundry Room, both the small and large fires approach a steady-state condition within the first several hundred seconds. The temperature rise due to the large fire is somewhat less than twice that of the small fire. The large error bars indicates that the variability within the Laundry Room is very high - the maximum small-fire temperatures are almost the same as the minimum large-fire temperatures.

In essence, each fire quickly creates a reservoir of hot gases in the Laundry Room, with the temperature of the reservoir depending, of course, on the fire size. These remain at more or less constant temperatures for long periods of time, during which the Control Room continuously heats up as energy is transported from the reservoir.

This behavior is not unexpected and these graphs are primarily useful as a baseline for comparison with conditions that occur in other scenarios.

4.4 Effects of Bilge Openings

Looking next at the effects of opening the bilges, we have two pairs of data sets with which to work - Tests 4_03 versus 4_05 and Test 4_07 versus 4_06. Air temperature increases in the Control Room and Laundry for these cases are shown in Figures 8 and 9, respectively.

It is clear from Figure 8 that opening the bilge hatches makes no difference in either the Control Room or the Laundry Room. This is the expected result because there is no effective mechanism by which the fire would heat the air inside the bilges. Even when the bilges are open, it is expected that the relatively cold air within will remain stagnant, thus making no appreciable contribution to conditions in the rest of the boat.

The same general result is seen in Figure 9, except that there is a small reduction in the magnitude of the temperature increase in the Control Room when the bilge was open. At its maximum (which occurred around +400 seconds), this difference amounted to only about 10 degrees.

4.5 Effects of Framebay Openings

The same four tests are used to illustrate the effects of opening the framebays but, this time, we compare 4_03 with 4_07 (Figure 10) and 4_05 with 4_06 (Figure 11).

The framebays provided a nearly direct path for the hot gases to rise from the Laundry to the Control Room and, as expected, they had a major impact on the Control Room temperature. Relative to the tests in which the framebays were closed, the two cases in which the framebays were open resulted in a nine-fold increase in the initial rate of rise of the Control Room temperature (about 15 - 18 degrees/min versus less than 2 degrees/min over the first 200 seconds). Also, much higher peak temperature increments were reached (slightly greater than 80 degrees as compared to about 30 degrees).

Both effects are caused by the reduction in transit time afforded by the more direct path through the framebays. In addition to permitting the fire gases to reach the Control Room more quickly, there is less cooling time so the gases are hotter when do they arrive.

In some respects, the Laundry Room results were more interesting. The initial period following ignition was virtually identical in all four tests, with the temperatures jumping 200 degrees within seconds. However, after this period, the temperatures continued to rise, albeit much more slowly,

until a near steady-state of 250 - 325 degrees was reached at about +500 - +750 seconds in the cases with closed framebays. In contrast, the open framebay cases peaked somewhat earlier and then began to decline. Presumably, this was caused by the more efficient removal of hot gases from the fire compartment once the circulation pattern through the framebays became established. In retrospect, this result should have been expected, but it is definitely a less obvious effect than that seen in the Control Room.

4.6 Effects of External Hatch Openings

The single most important issue motivating this study was the question of whether opening exterior hatches would provide additional oxygen to the fire, thereby permitting it to grow larger than it otherwise would have. Therefore, Figures 12 - 14 are probably the most critical figures in this report. As mentioned previously, H01 and H1 have been lumped together as "Sail" to simplify the presentation. Recall, from Table 3, that the first four cases in these figures represent zero, one, two and three open hatches, respectively, and that the last case is a different two-hatch-open situation.

Figure 12 shows Control Room and Laundry Room air temperature increases for all of the available exterior ventilation combinations. For the Control Room, in all of the cases in which any combination of external hatches were open, the temperature increase was greater than for the case where no external hatches are open. This is attributed to the increased circulation that is expected when external ventilation is provided. Under these circumstances, the more forceful circulation drives hot gases from the Laundry into the Control Room more efficiently, resulting in higher Control Room temperatures.

Furthermore, the four cases in which at least one hatch was open fell into two classes of two cases each. Tests 5_03 and 5_04 were indistinguishable, as were 5_07 and 5_06. Looking at the external hatch configurations (Table 3), we see that 5_03 and 5_04 differed only in that H2 was closed in the former and open in the latter. Likewise, Tests 5_07 and 5_06 also differed in exactly the same way. Based on this evidence, it appears that the state of H2 is not important when at least one other hatch is already open.

However, the temperature increase was slightly higher in the 5_03/04 cases than for 5_07/06. The difference between these classes was the state of the sail - closed in 5_03/04 and open in 5_07/06. Opening the sail reduced the Control Room temperature by several degrees in this situation, presumably because the sail, located directly above the Control Room, provided a vent for the hot gases.

In contrast, the Laundry Room temperature increase was less when one or more hatches was open than when all hatches were closed. Furthermore, there were no noticeable differences among the various open-hatch cases. This is consistent with the hypothesis of increased circulation when the exterior hatches are open - the relatively cool ambient air is being sucked into the fire compartment, thus lowering its temperature somewhat.

In the case of the Laundry Room, opening the sail seems to have no effect if H3 was already open. It was mentioned above that the effects seen when the sail and H3 were open (as compared to opening H3 alone) were attributed to the proximity of the sail to the Control Room. For the Laundry Room, it appears that all of the hatches were sufficiently far away that the limiting factor was the flow restriction within the boat, rather than the specific hatch configuration.

Figures 13 and 14, respectively, show O_2 and CO_2 concentrations for the same set of five tests. Note that, for the Control Room, readings from the upper and lower gas sensors have been averaged, as discussed above, whereas upper and lower values are shown separately for the Laundry Room. The prominent spikes in the graphs were caused by the occasional use of clean air

to purge soot and condensates from the gas sample lines. For the duration of each purge cycle, the gas analyzers were reading normal air values.

For the Control Room, both gases follow the same pattern that was seen in the temperature data - Test 5_03 and 5_04 cluster together, 5_07 and 5_06 form a second cluster and 5_20 is noticeably different from the other four cases. Again, the closed boat situation provides a better Control Room environment, at least for the initial 1000 seconds. During this period, the closed boat O_2 levels are higher, and the CO_2 levels lower, than in any of the open boat scenarios. This is consistent with the earlier hypothesis that opening any of the external hatches increases upwelling from the fire compartment. The gas data also supports the observation that, compared to the sail, H2 plays a minor rolê when H3 is open.

It is interesting to note that the concentrations of both gases level out in the 5_06/07 case but continue to decline (for O_2) or increase (for CO_2) in the 5_03/04 and 5_20 cases. Furthermore, the slopes of the decrease or increase are very similar in these three cases. Conditions appear to reach an equilibrium when the sail and H3 are both open, but not when only H3 is open.

Looking at the upper level in the Laundry Room, we again see pattern consistent with that seen for Laundry Room temperatures. The closed boat scenario leads to the worst conditions, with lower O_2 and higher CO_2. The clustering of the other cases is still present, although not nearly as pronounced as it was for the Control Room gas data, and follows the same general trends noted above.

The lower level O_2 measurements also are in agreement with the results discussed above and lend further support to the hypothesis. In the case of the lower level CO_2. all of the measurements fit the pattern except for Test 5_20, which lies between the 5_03/04 and 5_07/06 cases. Based on the observations cited above, it was expected that 5_20 would show the highest concentrations of CO_2.

At present, the cause of this discrepancy is not known. However, inspection of the same channel for the immediately preceding test (5_19) revealed that the sensor in question had not been working (the output was approximately zero for the entire test period, except for spikes to slightly less than 1% at about 500, 600 and 1500 seconds elapsed time). Obviously, the sensor was repaired before 5_20, but an error in the recalibration would explain the above observations.

5.0 CONCLUSIONS

For the most part, this study revealed no surprises. In particular, the effects of fire size and framebay openings were essentially what was expected. The temperature increase caused by the 1.05 m fire was about twice that of the 0.68 m fire - not quite as severe as might have been predicted based on the 3.3:1 ratio of fire sizes, probably because the larger fire was oxygen limited (O_2 dropped to about 10% in Test 4_03 as compared with about 15% in 4_01).

As anticipated, the primary effect of the framebays was to increase the efficiency of mass transport out of the Laundry Room, resulting in appreciably worse conditions in the Control Room as measured by both the rate of temperature increase and the magnitude of the increase. A small cooling effect was seen in the Laundry Room as a result of the increased loss of hot gases.

Prior to the Submarine Ventilation Doctrine tests, it was suggested that opening the bilge hatches might provide an additional source of oxygen and thereby contribute to fire growth. Based on this study, the bilge hatches appear to have had no substantive effect in the fire compartment and, at most, resulted in a slight reduction in the temperature rise in the Control Room. In retrospect, this is not surprising, since the bilges are void spaces filled with cold air located below the level of the

fire. With no circulation through them and no heat source in them, there is no driving force capable of moving bilge air up and into the fire compartment.

The effects of opening external hatches may be summarized as follows:

1. Conditions in the Control Room deteriorated whenever <u>any</u> exterior hatches were open (this includes increases in temperature and CO_2 concentration and a decrease in O_2)[2].
2. Conditions in the Laundry Room improved when one or more external hatches was open (lower temperature, lower CO_2 and higher O_2).
3. Opening H2 had little effect when at least one of the other hatches was also open.
4. The adverse effect on Control Room tenability caused by opening H3 may be slightly reduced by also opening the sail.
5. Atmospheric composition in both the Control Room and the Laundry appear to reach an equilibrium when both the sail and H3 are open, but not when only H3 is open.
6. When only H3 is open, the deterioration in Control Room and Laundry atmospheric composition tends to parallel that of the closed boat case.

In practical terms, the above observations suggest that, for the Laundry Room fire scenario, keeping the boat closed is better for maintaining Control Room habitability but also tends to make conditions in the fire compartment slightly worse. If the decision is made to open any hatches, it appears best to open H3 and, if H3 is opened, then the sail should be opened also. Finally, H2 may be important as an ingress/egress route, but seems to have a negligible effect on either the fire or the tenability of the Control room.

These findings listed above are consistent with the hypothesis that opening any of the external hatches increases mass transport from the fire compartment into the upper parts of the boat. This is undoubtedly a general principal, but it will have different effects and, therefore, suggest different strategies, depending on the location of the fire and the compartment(s) of interest. For example, it seems likely that, had we been more interested in conditions in the Combat Systems space, H2 would have been very important as a mitigating factor and the sail might well have had a smaller influence.

6.0 ACKNOWLEDGMENTS

We wish to thank Jean Bailey (Naval Research Laboratory), for her assistance with data processing on the MassComp and for her helpful discussions and comments during the preparation of this report. Thanks also to Alex Maranghides (GeoCenters, Inc.) for his suggestions regarding possible instrumentation problems, and to Mike Ferreira (Hughes Associates, Inc.) for the time spent tracking down test logs and answering "just one more question" about the actual execution of Submarine Ventilation Doctrine tests. Finally, we are grateful to the many Naval Research Laboratory and Hughes Associates, Inc. personnel who conducted the Submarine Ventilation Doctrine tests which provided the raw data for this work.

[2] It should be noted, however, that for the case of pierside fires, maintaining habitable conditions in the Control Room is not a critical objective. In this situation, it is more important to provide a safe reentry route through H2 or H3. Using the sail as a vent is likely to aid this endeavor.

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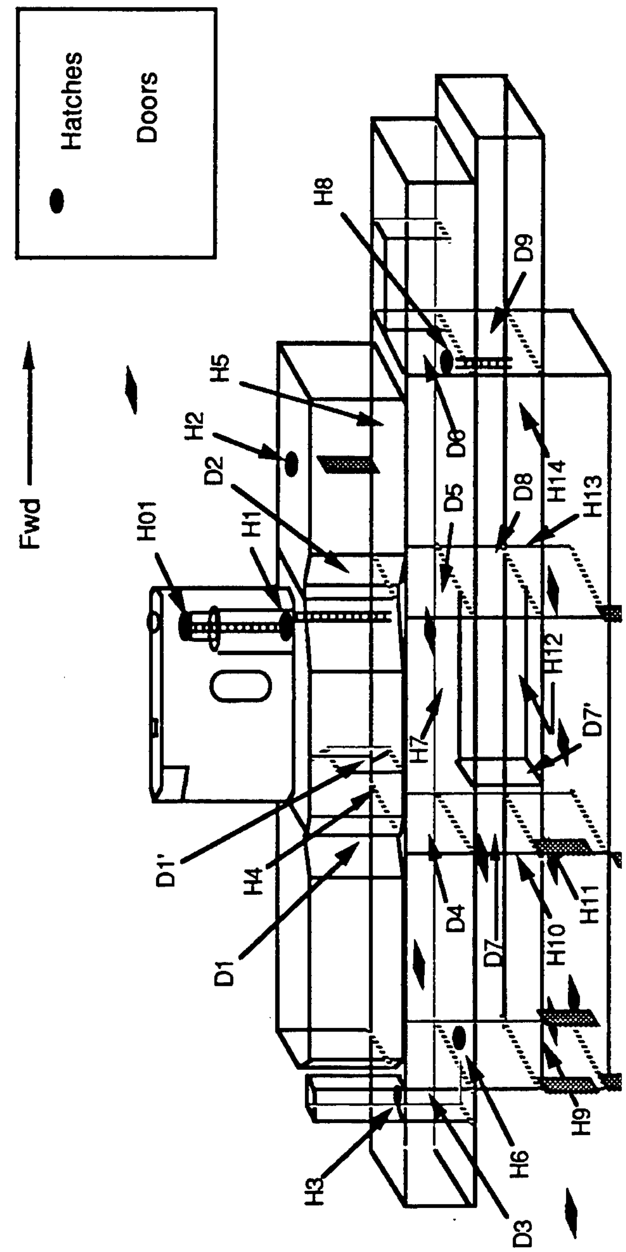


Figure 1. Isometric view of the SHADWELL/688 test area, as viewed from the well deck.

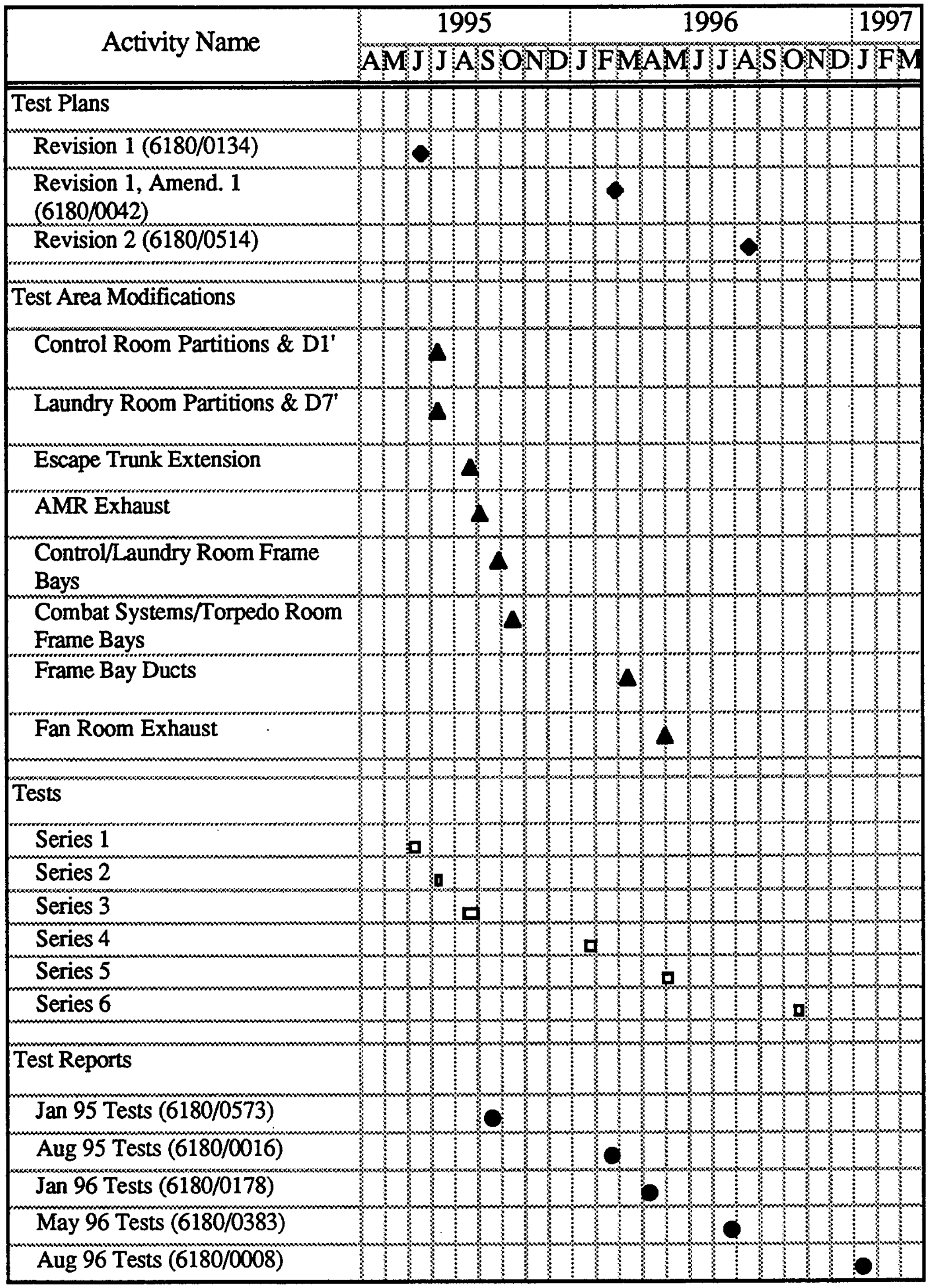


Figure 2. Timeline of activities associated with the Submarine Ventilation Doctrine test program.

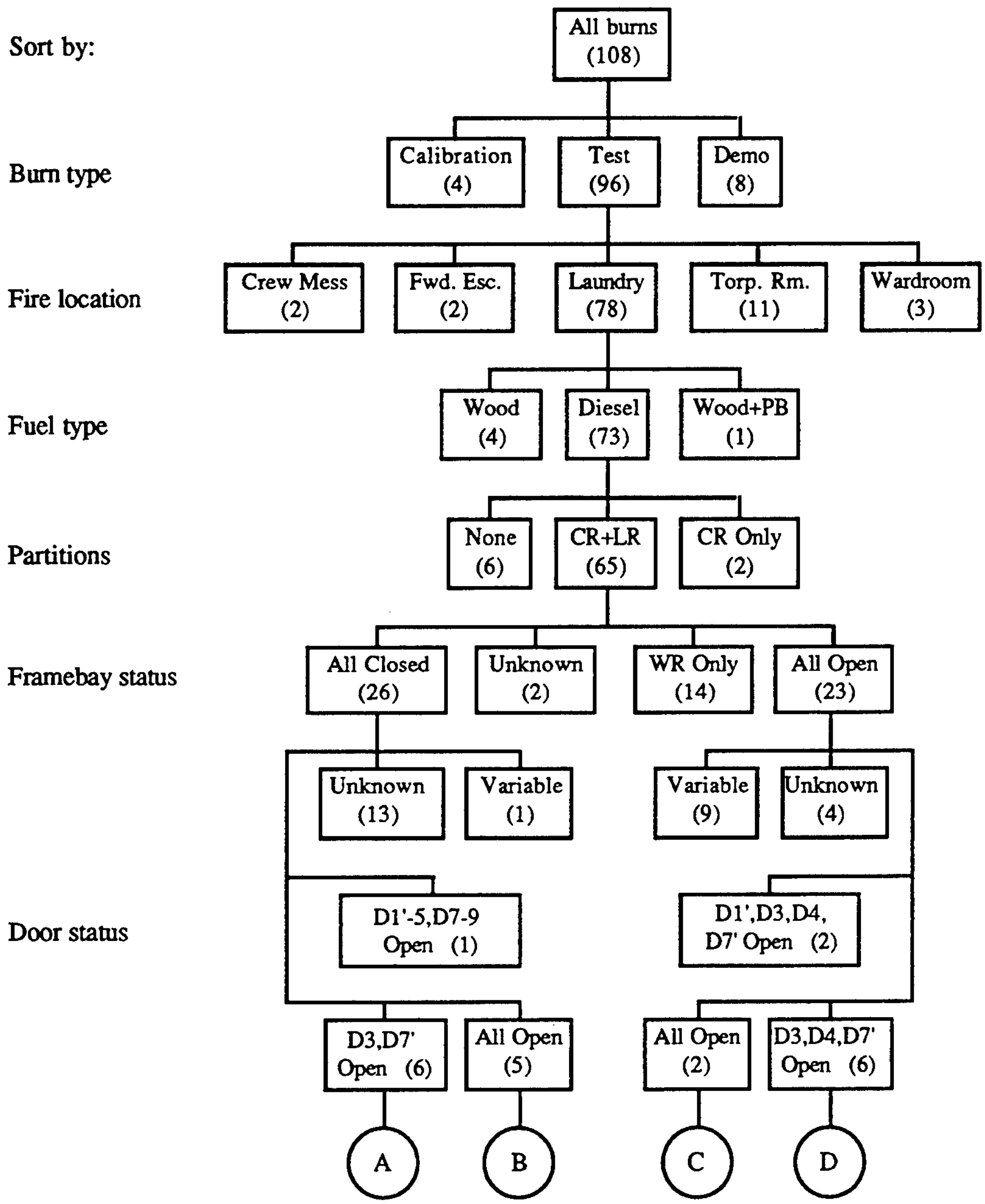


Figure 3A. All cases were sorted according to the test configuration to identify replicates and test pairs which differed only by one parameter. Of the 23 cases in which all framebays were open, ducts were not installed in four (including both of the category C cases). Ducts were installed for the remaining 19 cases, which includes all of category D.

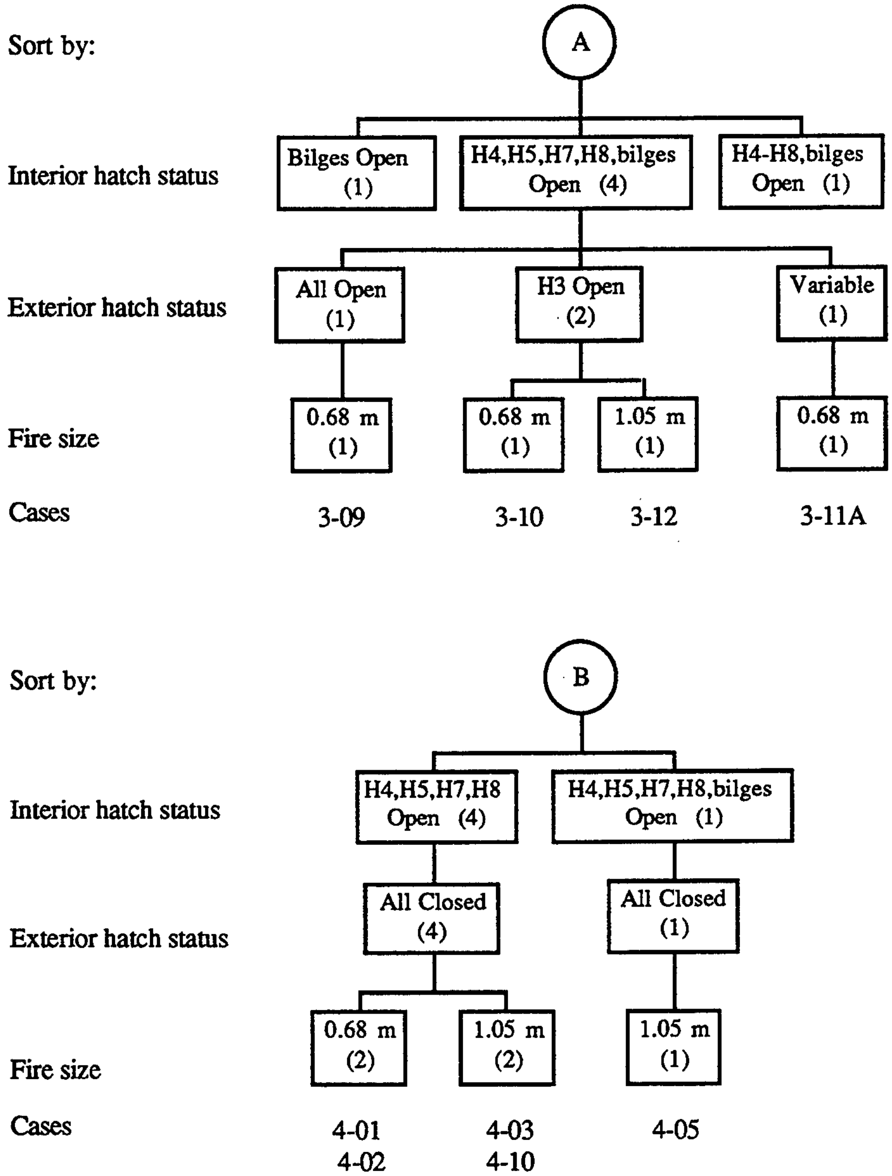
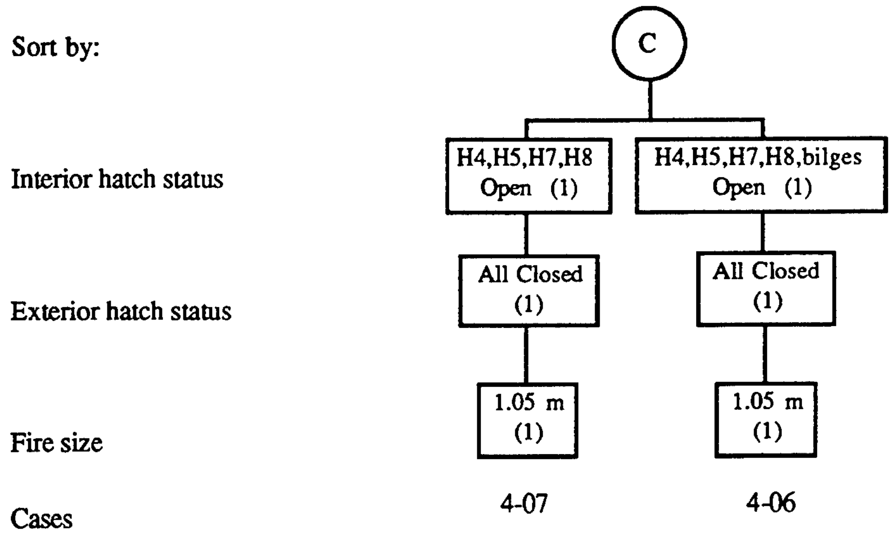


Figure 3B. Data for the tests in category A was not available for analysis. In category B, test 4_10, nominally a replicate of 4_03 based on the standard parameters, was actually unique in that the ventilation dampers were closed to prevent passive smoke and gas transport.



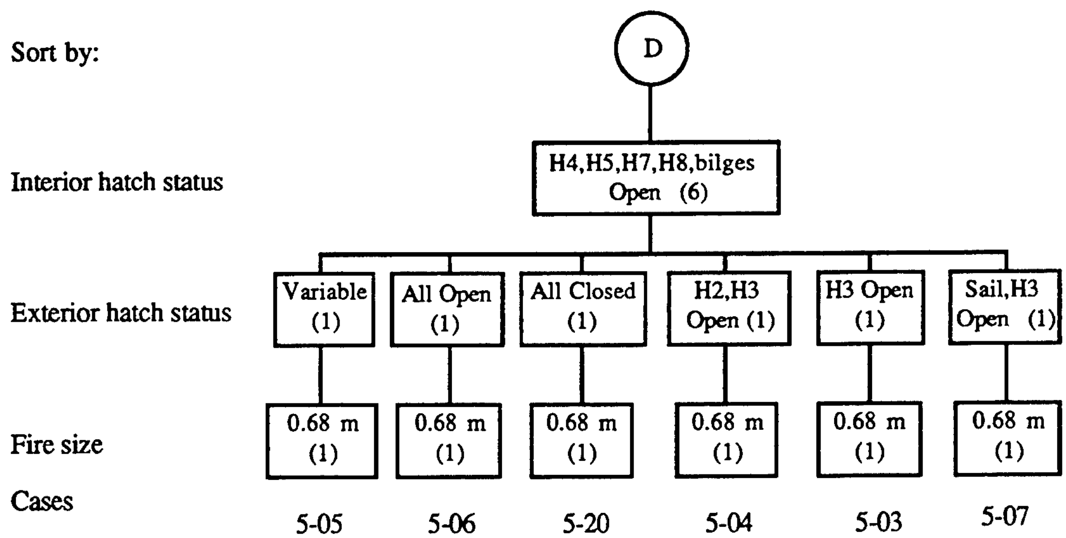


Figure 3C. As indicated in Figure 3A, there were no framebay ducts for either of the tests in category C. The ducts were installed for the tests in category D.

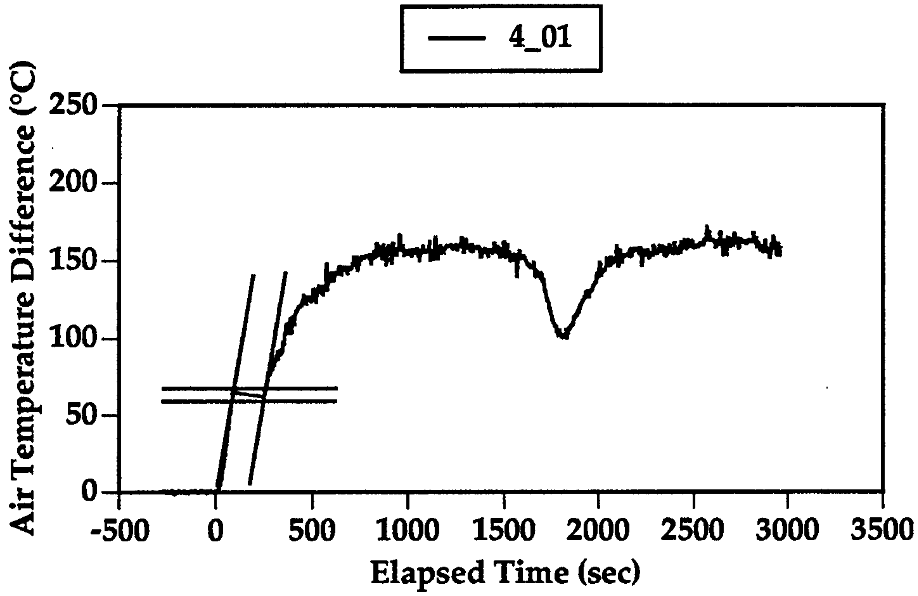


Figure 4A. Original Laundry Room air temperature increases from Test 4_01. As indicated by the black lines, the slopes before and after the gap (+89 to +249 seconds) are the same and the difference in the absolute values is within the range due to noise.

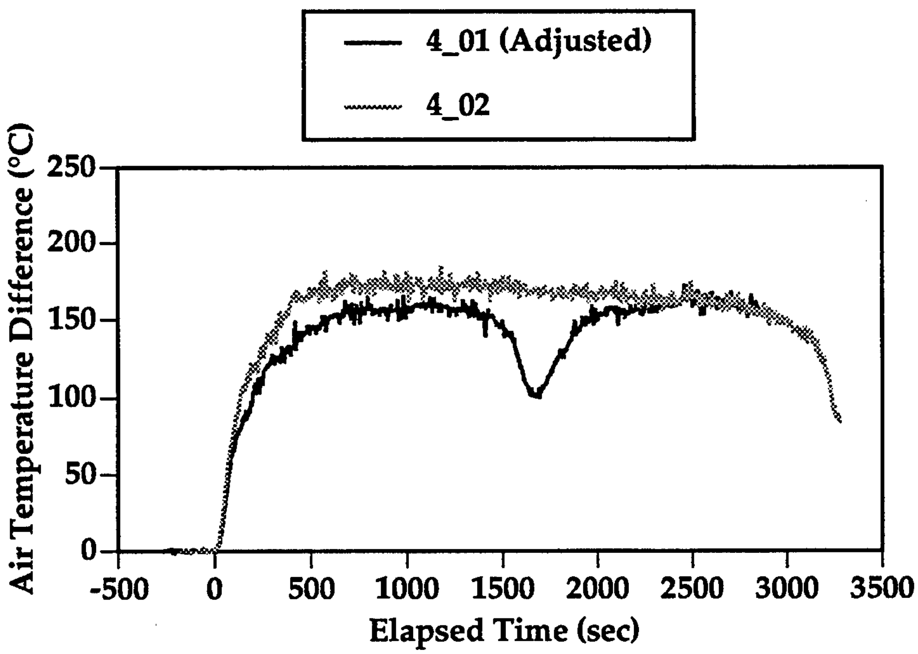


Figure 4B. Adjusted Laundry Room air temperature increases from Test 4_01 compared with Laundry Room air temperatures from Test 4_02. The close agreement between the two curves in the vicinity of +89 seconds supports the hypothesis that the data gap was due to the MassComp clock skipping forward.

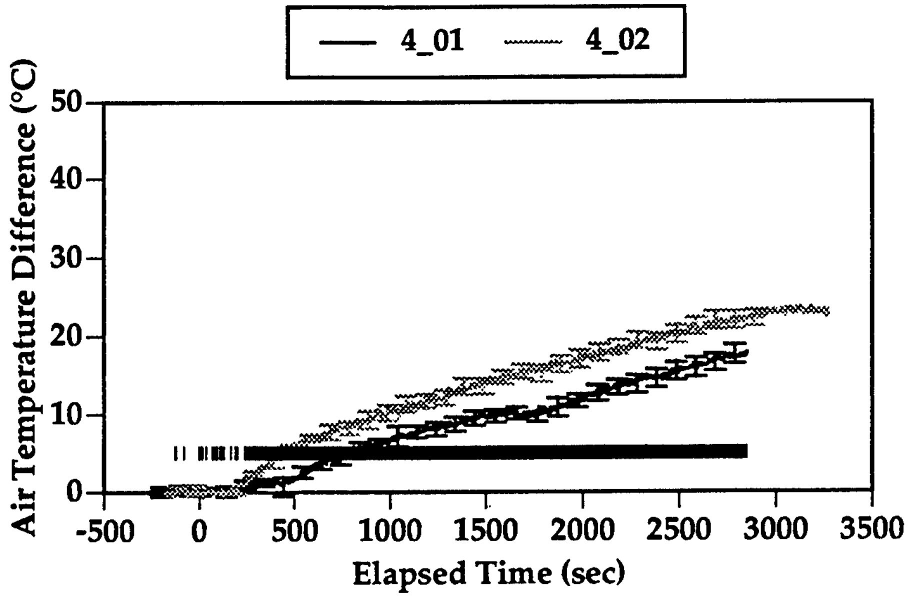


Figure 5A. Control Room air temperature increases in replicate tests 4_01 and 4_02. The bold, horizontal lines indicate periods during which the t-test threshold of significance (95% confidence limit) was exceeded. Error bars represent one standard deviation.

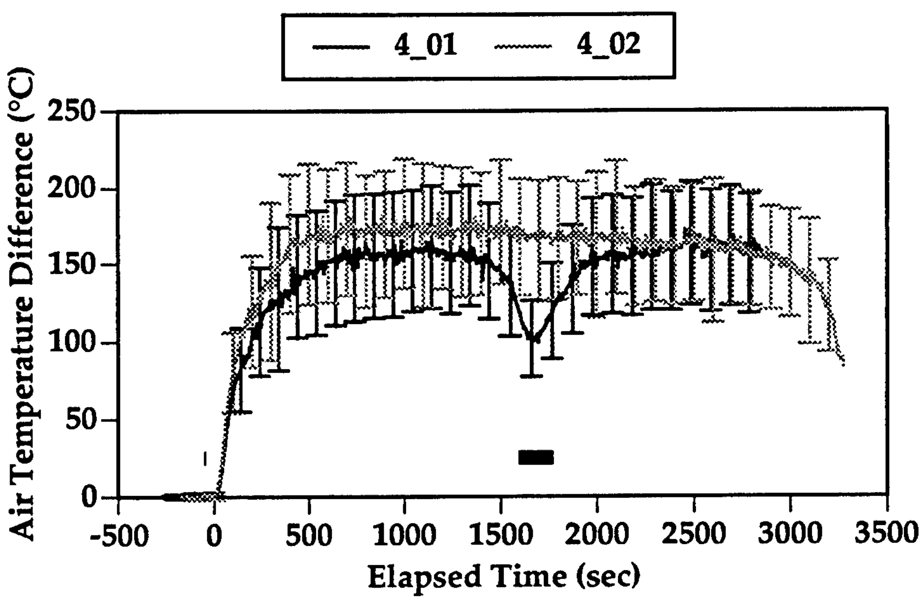


Figure 5B. Laundry Room air temperature increases in replicate tests 4_01 and 4_02. The bold, horizontal lines indicate periods during which the t-test threshold of significance (95% confidence limit) was exceeded. Error bars represent one standard deviation.

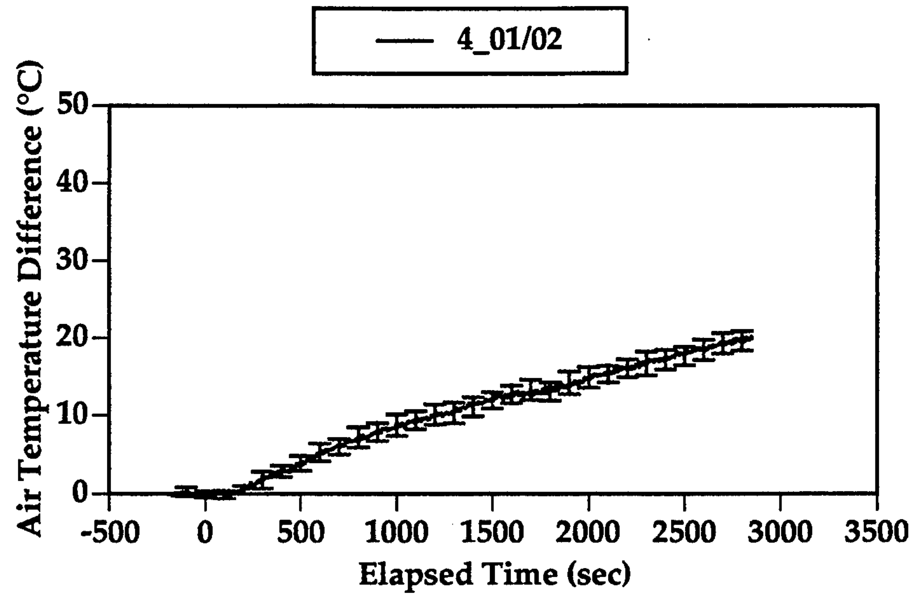


Figure 6A. Results of combining Control Room air temperature increase data from Tests 4_01 and 4_02. Error bars represent one standard deviation.

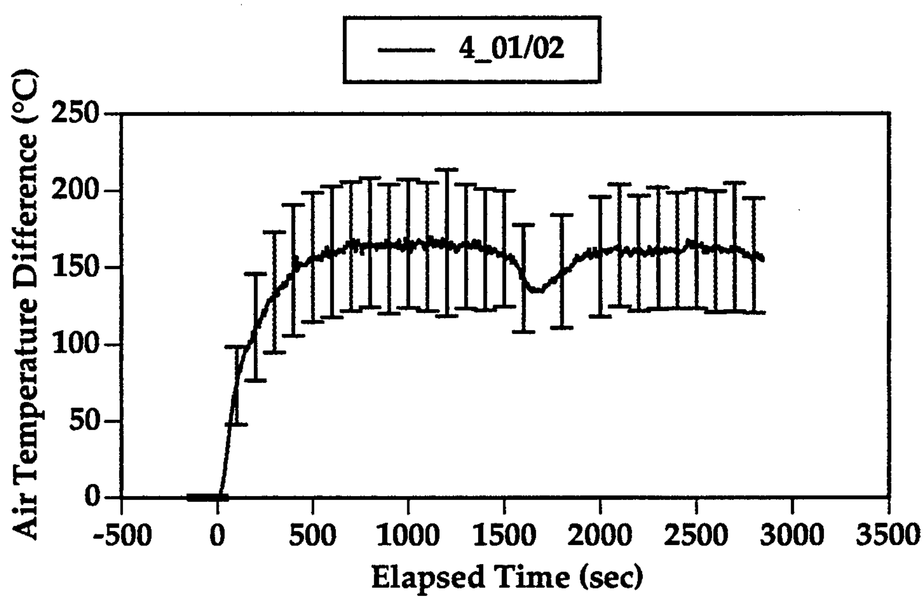


Figure 6B. Results of combining Laundry Room air temperature increase data from Tests 4_01 and 4_02. Error bars represent one standard deviation.

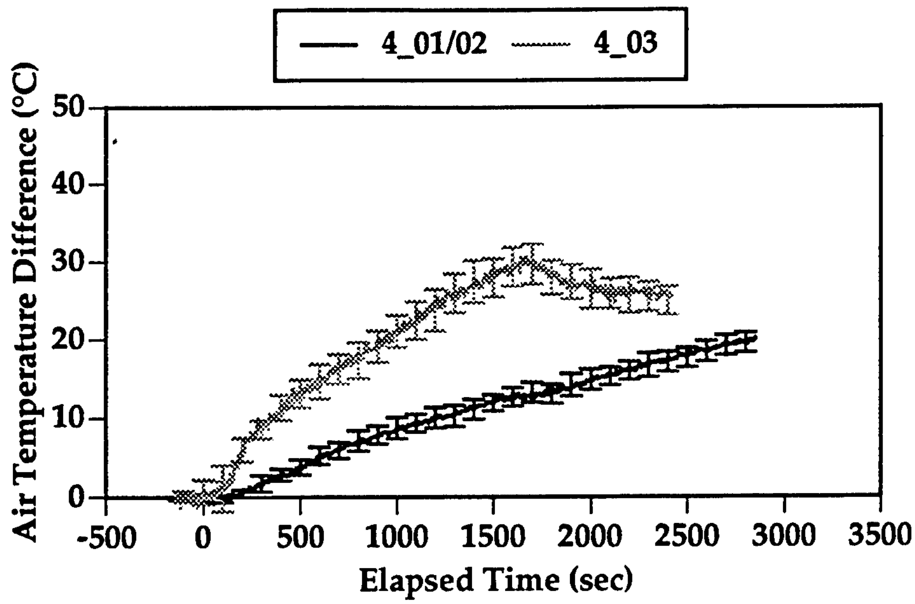


Figure 7A. Effects of fire size, based on comparison of Control Room air temperature increases in Tests 4_01/02 and 4_03. Error bars represent one standard deviation.

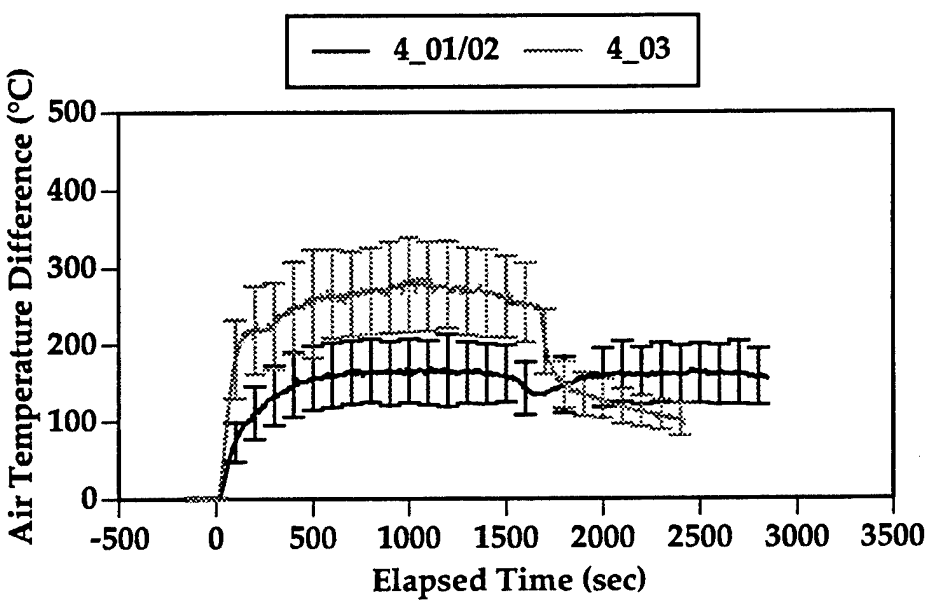


Figure 7B. Effects of fire size, based on comparison of Laundry Room air temperature increases in Tests 4_01/02 and 4_03. Error bars represent one standard deviation.

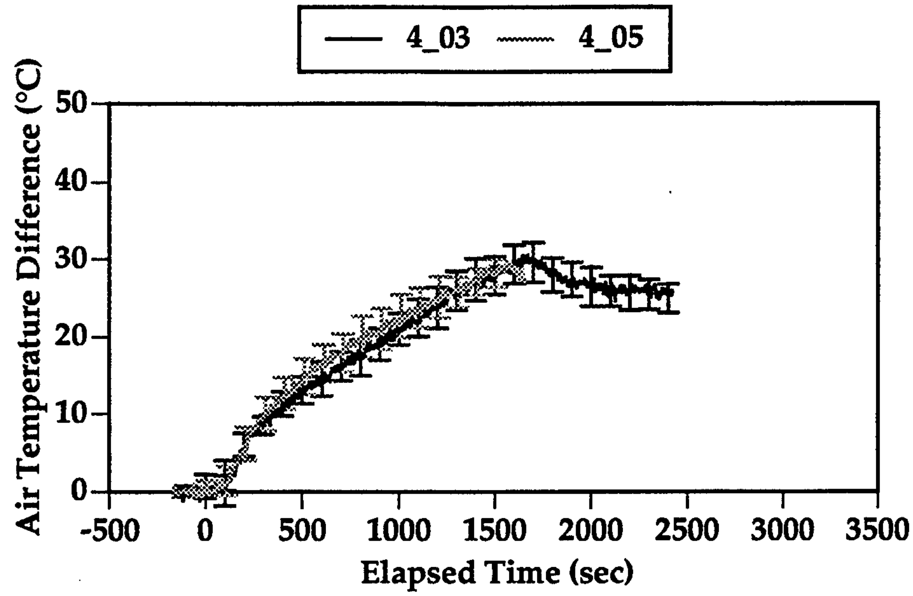


Figure 8A. Comparison of Control Room air temperature increases for closed bilges (4_03) and open bilges (4_05) for category B tests. Error bars represent one standard deviation.

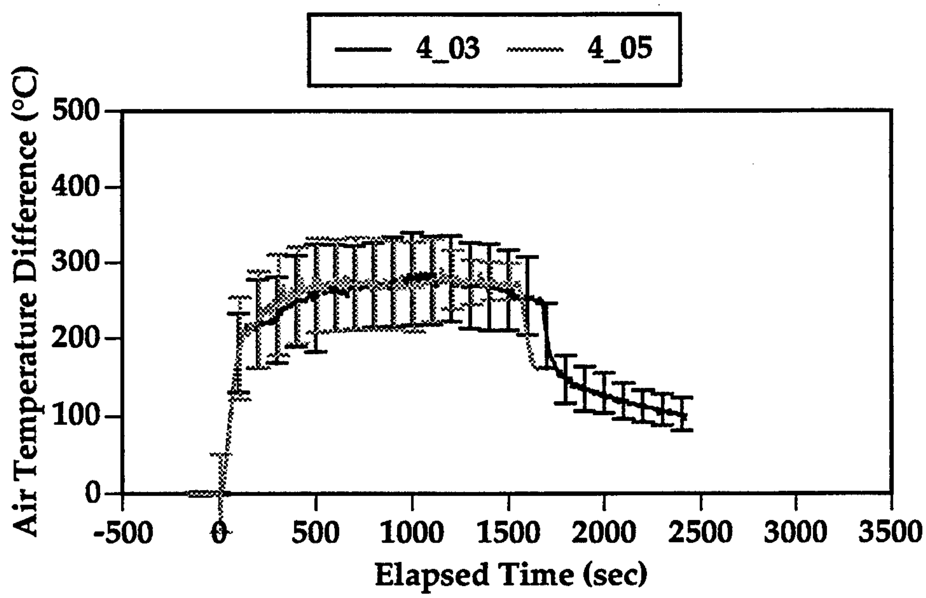


Figure 8B. Comparison of Laundry Room air temperature increases for closed bilges (4_03) and open bilges (4_05) for category B tests. Error bars represent one standard deviation.

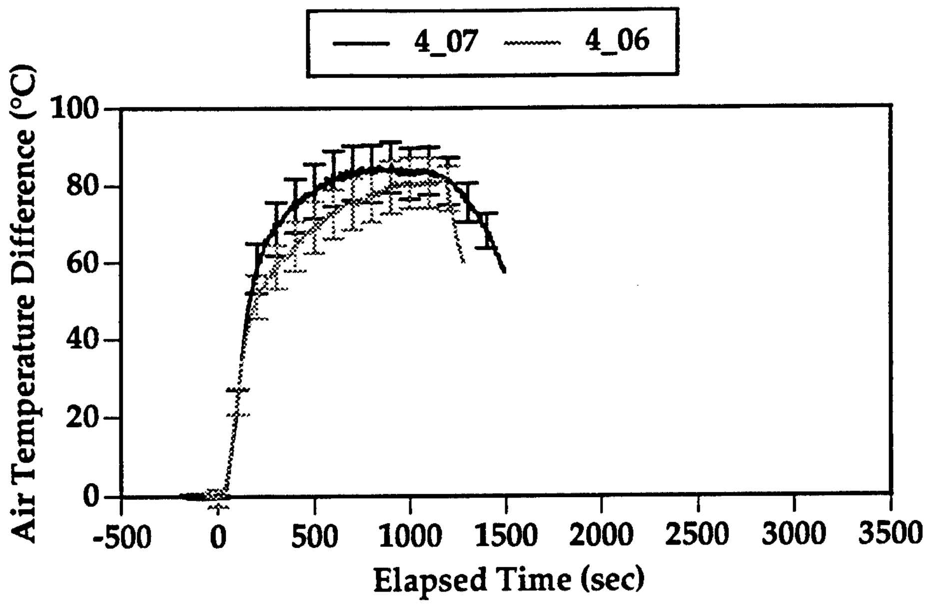


Figure 9A. Comparison of Control Room temperature increases for closed bilges (4_07) and open bilges (4_06) for category C tests. Error bars represent one standard deviation.

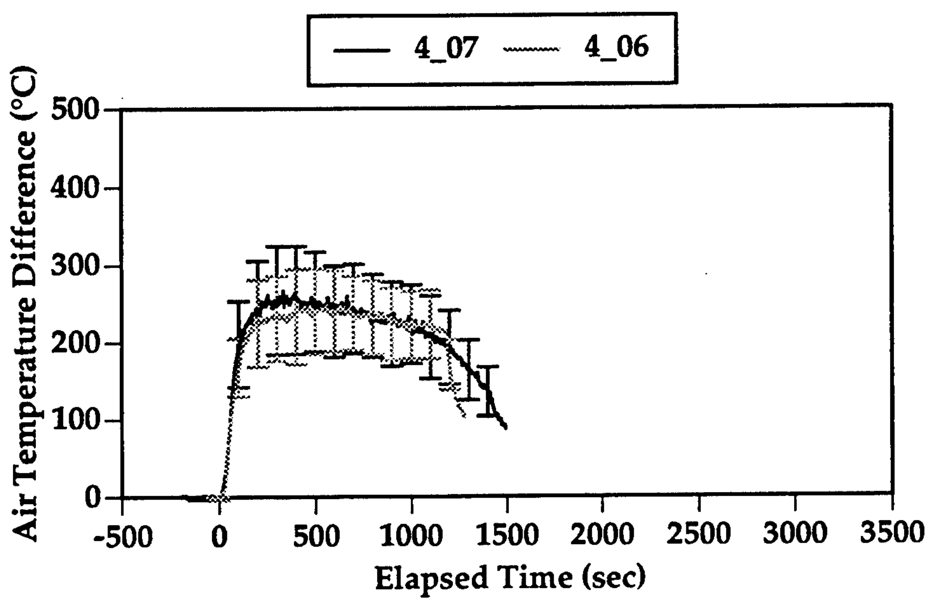


Figure 9B. Comparison of Laundry Room temperature increases for closed bilges (4_07) and open bilges (4_06) for category C tests. Error bars represent one standard deviation.

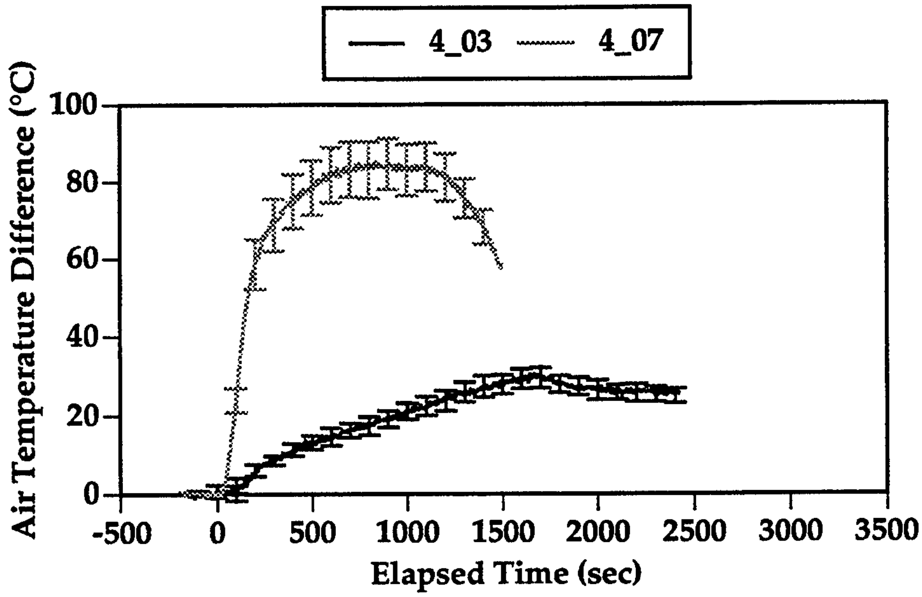


Figure 10A. Control Room air temperature increase with closed (4_03) and open (4_07) framebays for the closed bilge case. Error bars represent one standard deviation.

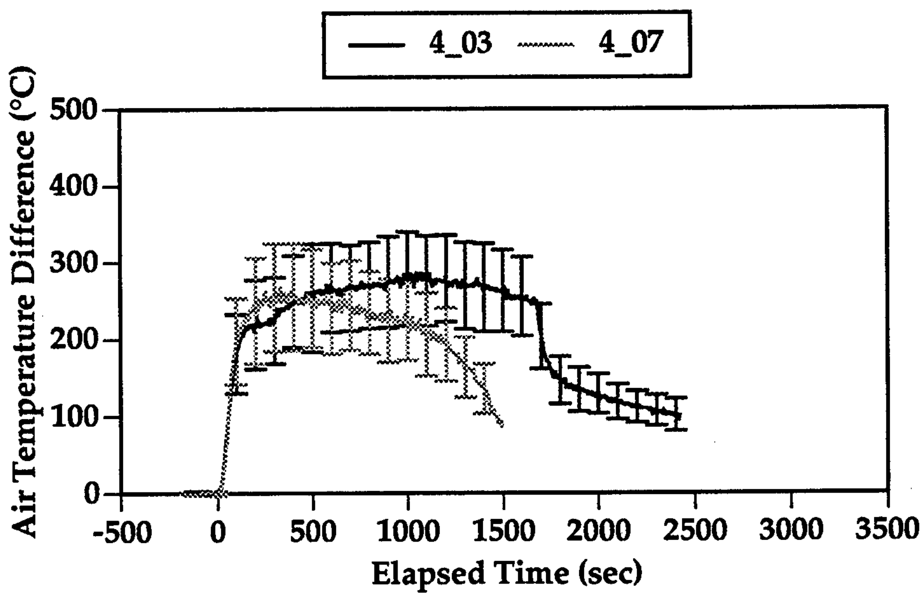


Figure 10B. Laundry Room air temperature increase with closed (4_03) and open (4_07) framebays for the closed bilge case. Error bars represent one standard deviation.

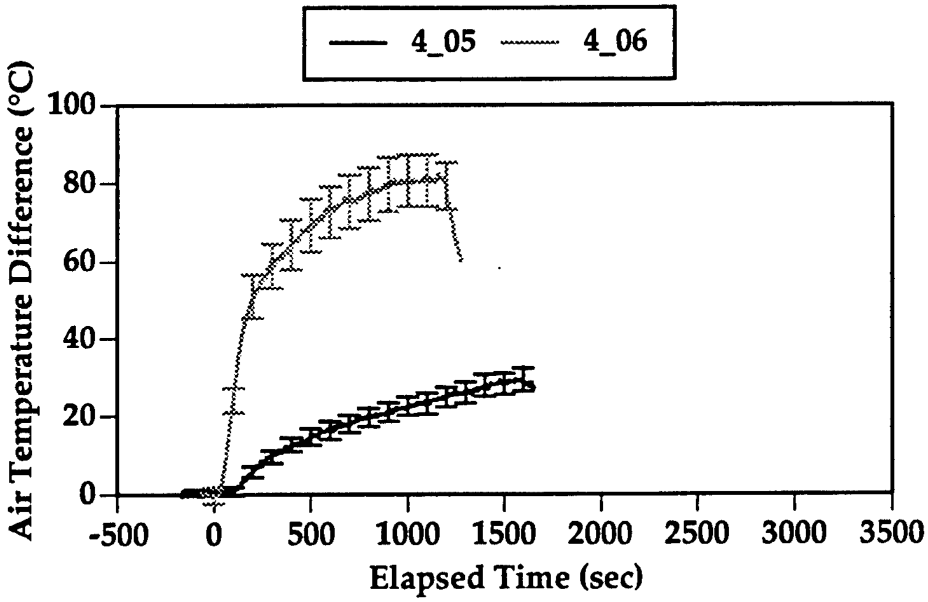


Figure 11A. Control Room air temperature increase with closed (4_05) and open (4_06) framebays for the open bilge case. Error bars represent one standard deviation.

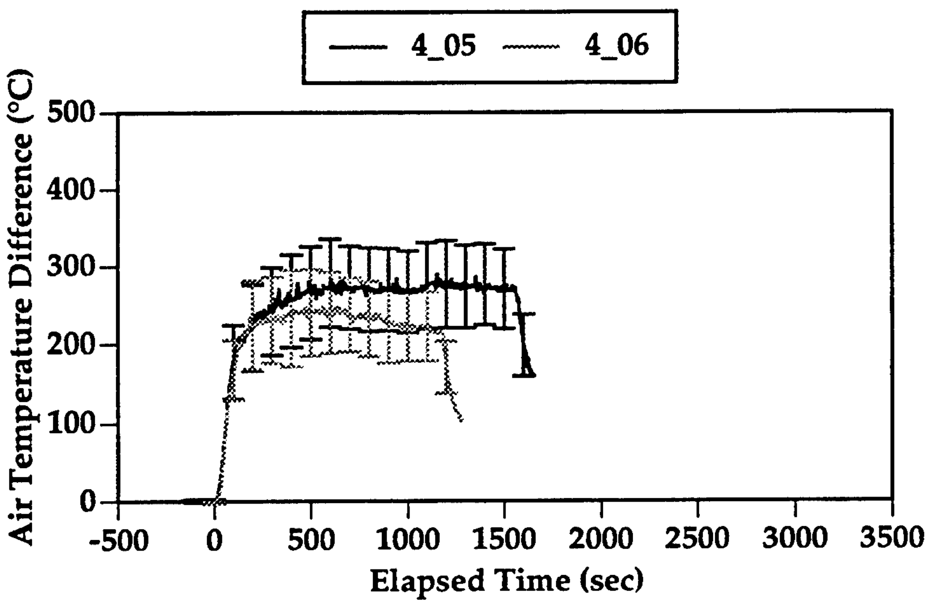


Figure 11B. Laundry Room air temperature increase with closed (4_05) and open (4_06) framebays for the open bilge case. Error bars represent one standard deviation.

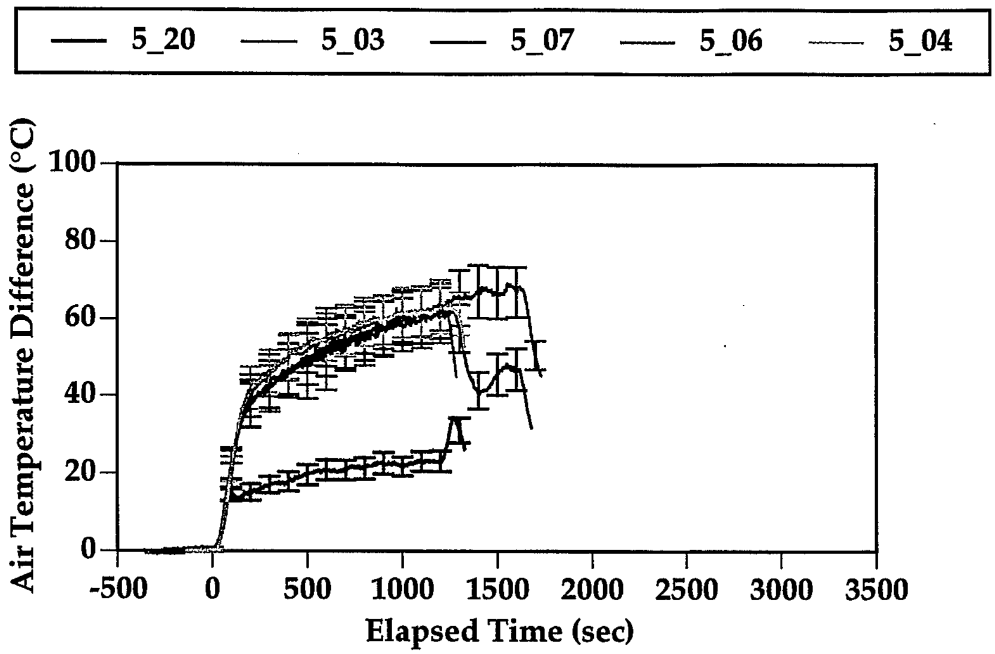


Figure 12A. Comparison of Control Room air temperature increases for five states of the external hatches: All closed (5_20), H3 open (5_03), H3 & Sail open (5_07), All open (5_06) and H2 & H3 open (5_04). Error bars represent one standard deviation.

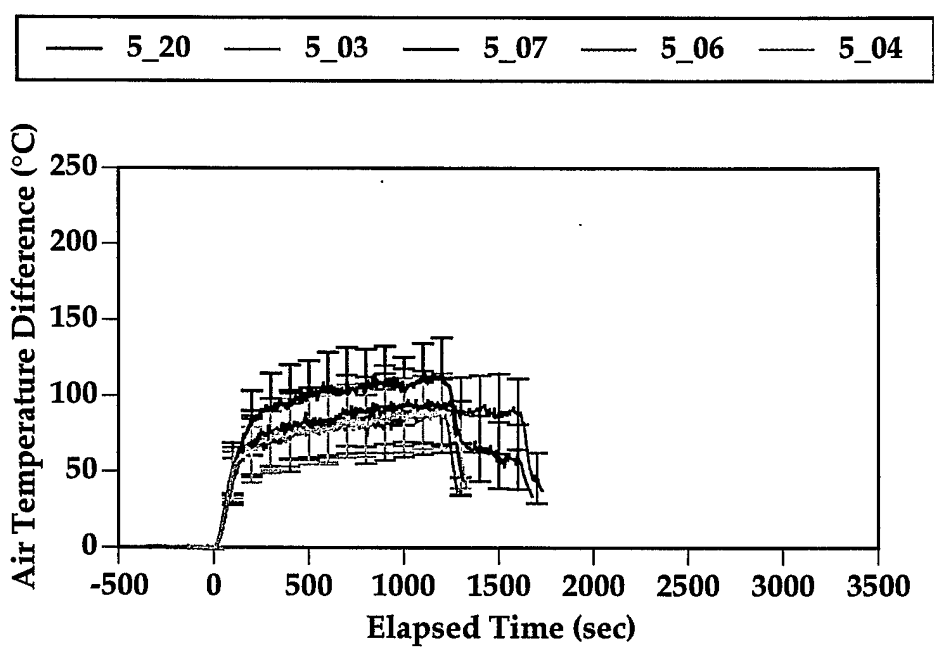


Figure 12B. Comparison of Laundry Room air temperature increases for five states of the external hatches: All closed (5_20), H3 open (5_03), H3 & Sail open (5_07), All open (5_06) and H2 & H3 open (5_04). Error bars represent one standard deviation.

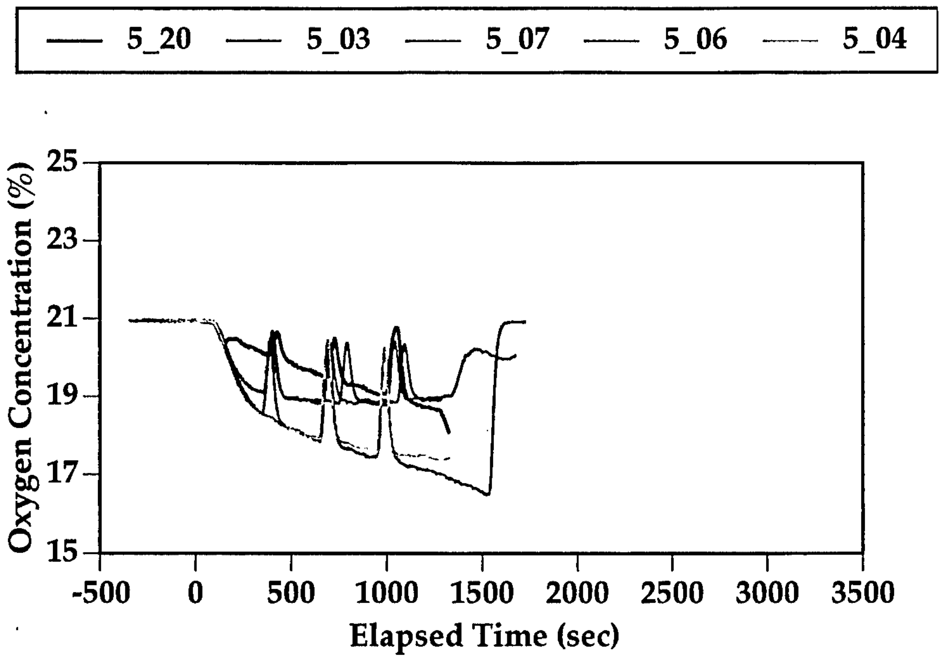


Figure 13A. Comparison of Control Room mean oxygen concentrations for five states of the external hatches: All closed (5_20), H3 open (5_03), H3 & Sail open (5_07), All open (5_06) and H2 & H3 open (5_04). The regular series of upward spikes were due to intermittent air purging of the gas sample lines to reduce the buildup of condensates and soot.

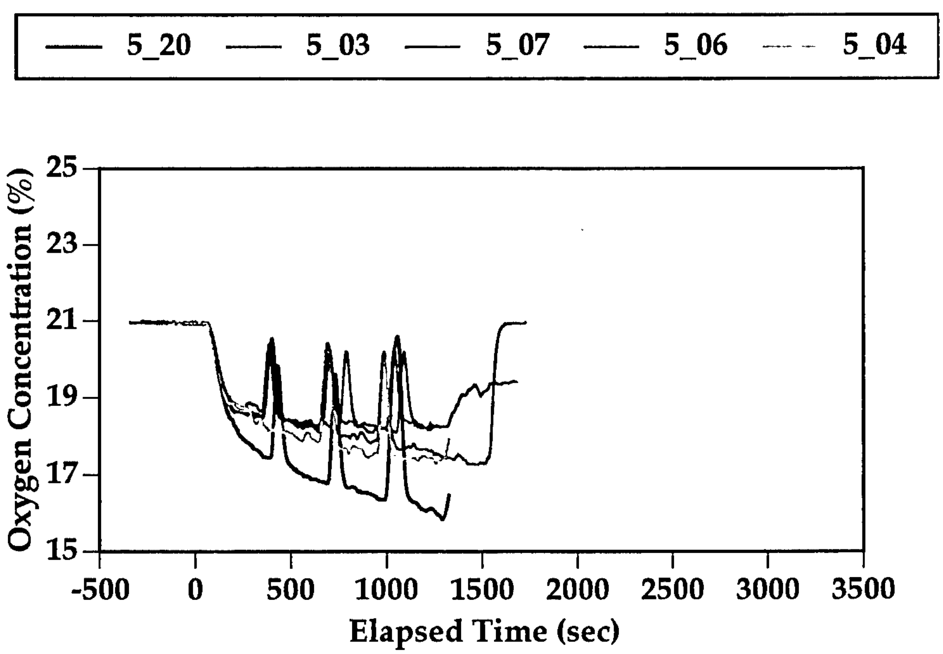


Figure 13B. Comparison of Laundry Room upper level oxygen concentrations for five states of the external hatches: All closed (5_20), H3 open (5_03), H3 & Sail open (5_07), All open (5_06) and H2 & H3 open (5_04). The regular series of upward spikes were due to intermittent air purging of the gas sample lines to reduce the buildup of condensates and soot.

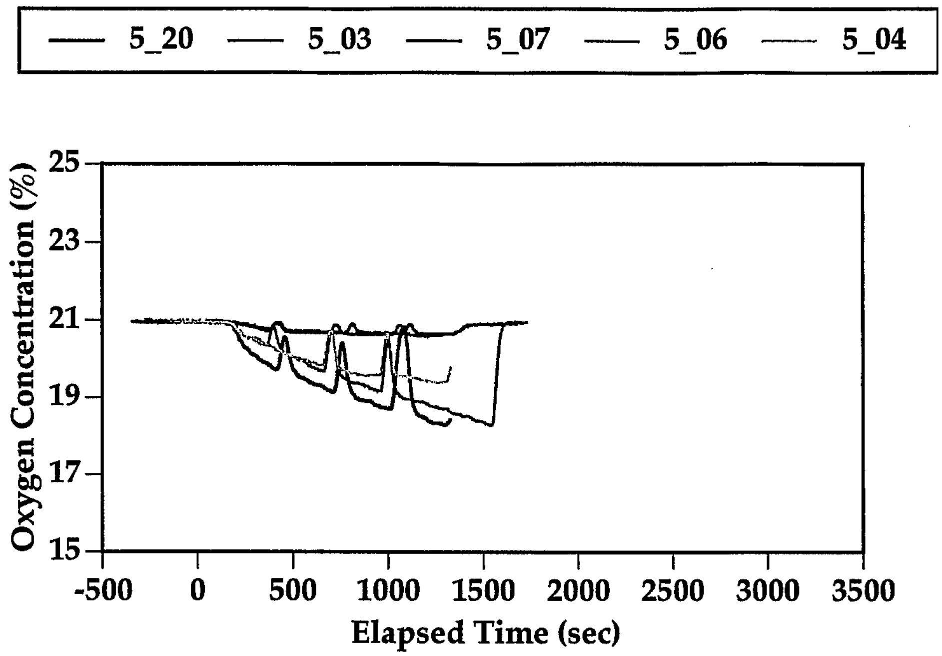


Figure 13C. Comparison of Laundry Room lower level oxygen concentrations for five states of the external hatches: All closed (5_20), H3 open (5_03), H3 & Sail open (5_07), All open (5_06) and H2 & H3 open (5_04). The regular series of upward spikes were due to intermittent air purging of the gas sample lines to reduce the buildup of condensates and soot.

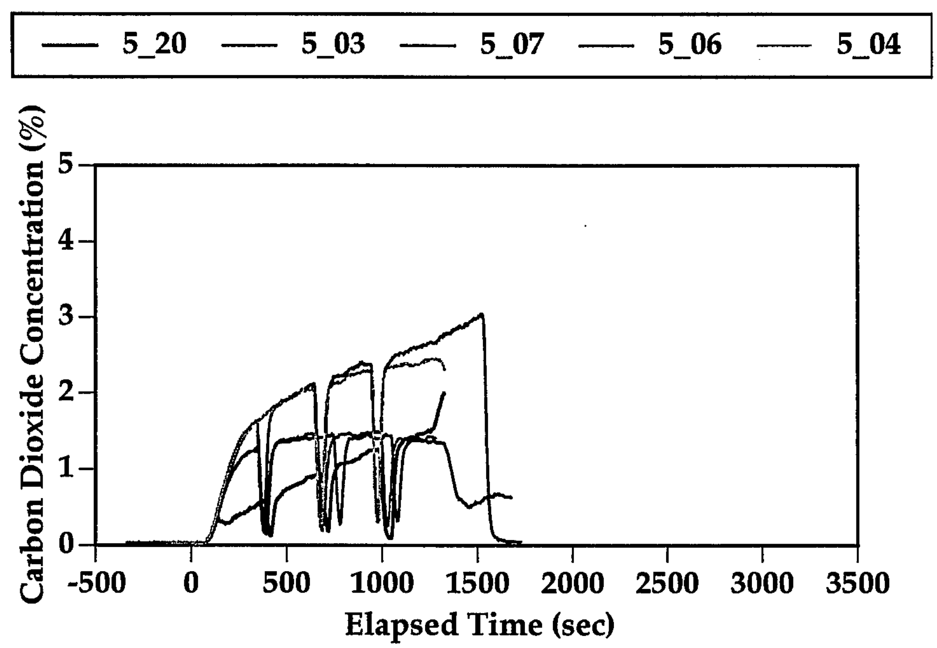


Figure 14A. Comparison of Control Room mean carbon dioxide concentrations for five states of the external hatches: All closed (5_20), H3 open (5_03), H3 & Sail open (5_07), All open (5_06) and H2 & H3 open (5_04). The regular series of downward spikes were due to intermittent air purging of the gas sample lines to reduce the buildup of condensates and soot.

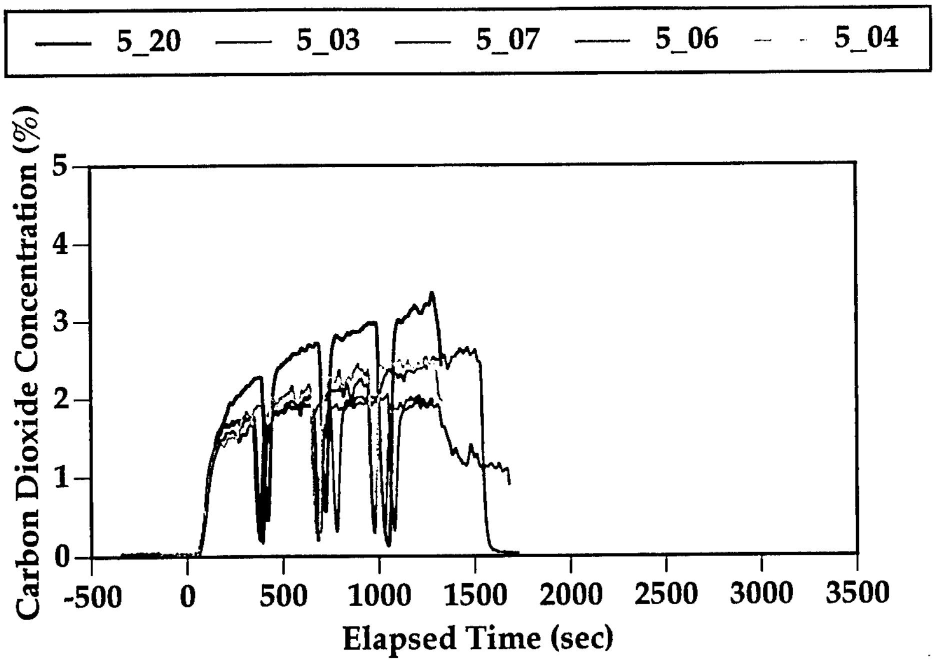


Figure 14B. Comparison of Laundry Room upper level carbon dioxide concentrations five states of the external hatches: All closed (5_20), H3 open (5_03), H3 & Sail open (5_07), All open (5_06) and H2 & H3 open (5_04). The regular series of downward spikes were due to intermittent air purging of the gas sample lines to reduce the buildup of condensates and soot.

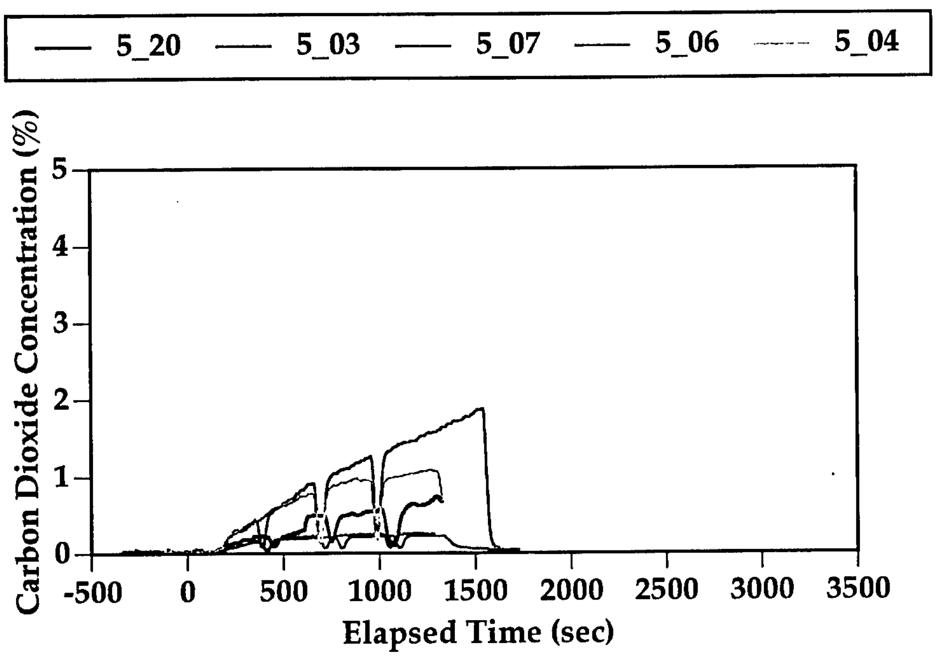


Figure 14C. Comparison of Laundry Room lower level carbon dioxide concentrations for five states of the external hatches: All closed (5_20), H3 open (5_03), H3 & Sail open (5_07), All open (5_06) and H2 & H3 open (5_04). The regular series of downward spikes were due to intermittent air purging of the gas sample lines to reduce the buildup of condensates and soot.

Test	4_01 4_02	4_03
Fire Size (m)	0.68	1.05
Other Parameters	Exterior hatches closed Bilges closed	
Category	B	

Table 1. Effects of fire size. Tests 4_01 and 4_02 were replicates of the same scenario and were combined into a single data set for the small fire case. That set was then compared with 4_03.

Test	4_03	4_05	4_07	4_06
Bilge Status	Closed	Open	Closed	Open
Other Parameters	1.05 m fire; Exterior hatches closed		1.05 m fire; Exterior hatches closed	
Category	B (Closed framebays)		C (Open framebays)	

Table 2. Effects of opening bilges and framebays. Tests 4_03 and 4_05 were compared, as were 4_07 and 4_06 to see the effects of opening the bilge hatches. Framebays were closed in Category B and open in Category C, therefore, by comparing 4_03 with 4_07 and 4_05 with 4_06, the effects of the framebays could be investigated.

Test	5_20	5_03	5_07	5_06	5_04
Sail Status	Closed	Closed	Open	Open	Closed
H2 Status	Closed	Closed	Closed	Open	Open
H3 Status	Closed	Open	Open	Open	Open
Other Parameters	0.68 m fire; Bilges open				
Category	D				

Table 3. Effects of opening various combinations of external hatches. H01 and H1, which were located at the top and bottom of the sail, respectively, have been combined into one line for clarity. If either of these hatches was closed, then the sail access was closed. This sequence of tests represents progressive opening of hatches (5-20, 5_03, 5_07 and 5_06), followed by closing of one hatch (5_04).

Cmpts	Sensors	Units
Sail	Air Thermocouple	Deg. C
Fan Room	Bulkhead Thermocouple	%
Control Room	Deck Thermocouple	% Transmission
Combat Systems	Overhead Thermocouple	PSI
Escape Trunk	Oxygen	Volts
Crew Messroom	Carbon Dioxide	kW/m^2
Wardroom	Carbon Monoxide	
Crew Living	Calorimeter	
CPO Living	Radiometer	
AMR	Optical Density	
Laundry	Pressure	
Torpedo Room	Logic	
Storeroom	Flame Thermocouple	
AMR Bilge		
Battery Compartment		
Bilge		
Laundry Passageway		
Nav. Equip.		
unknown		

Table 4. Compartment, sensor and units lists entered into STAT for the analysis described in this report. The compartment designation "unknown" was used for two sensors whose location relative to the Control Room partition was not documented.

Chan	Sensor	Units	Cmpt	X (m)	Y (m)	Z (m)
60.1	Air Thermocouple	Deg. C	Laundry Passageway	0	0	2.5
61.1	Air Thermocouple	Deg. C	Laundry Passageway	0	0	2
62.1	Air Thermocouple	Deg. C	Laundry Passageway	0	0	1.5
63.1	Air Thermocouple	Deg. C	Laundry Passageway	0	0	1
64.1	Air Thermocouple	Deg. C	Laundry Passageway	0	0	0.5
65.1	Air Thermocouple	Deg. C	Laundry Passageway	0	0	0.05
66.1	Air Thermocouple	Deg. C	Laundry Passageway	0	0	0
67.1	Air Thermocouple	Deg. C	Laundry Passageway	0	0	0
73.1	Air Thermocouple	Deg. C	Control Room	0	0	2.5
74.1	Air Thermocouple	Deg. C	Control Room	0	0	2
75.1	Air Thermocouple	Deg. C	Control Room	0	0	1.5
76.1	Air Thermocouple	Deg. C	Control Room	0	0	1
77.1	Air Thermocouple	Deg. C	Control Room	0	0	0.5
78.1	Air Thermocouple	Deg. C	Nav. Equip.	0	0	2.5
79.1	Air Thermocouple	Deg. C	Nav. Equip.	0	0	2
80.1	Air Thermocouple	Deg. C	Nav. Equip.	0	0	1.5
81.1	Air Thermocouple	Deg. C	Nav. Equip.	0	0	1
82.1	Air Thermocouple	Deg. C	Nav. Equip.	0	0	0.5

Table 5. The channel list for test series 4, as entered into STAT. Channels which were not required for the analysis have been omitted and file sequence numbers have been appended to the channel numbers. Z is elevation above the compartment deck; X and Y can refer to any user-specified coordinate system but were not used in the present work.

Chan	Sensor	Units	Cmpt	X (m)	Y (m)	Z (m)
129.1	Air Thermocouple	Deg. C	Laundry	0	0	2.5
130.1	Air Thermocouple	Deg. C	Laundry	0	0	2
131.1	Air Thermocouple	Deg. C	Laundry	0	0	1.5
132.1	Air Thermocouple	Deg. C	Laundry	0	0	1
133.1	Air Thermocouple	Deg. C	Laundry	0	0	0.5
134.1	Air Thermocouple	Deg. C	Laundry	0	0	0.05
135.1	Flame Thermocouple	Deg. C	Laundry	0	0	0
136.1	Flame Thermocouple	Deg. C	Laundry	0	0	0
137.1	Overhead Thermocouple	Deg. C	Laundry	0	0	2.56
138.1	Deck Thermocouple	Deg. C	Laundry	0	0	0
142.1	Deck Thermocouple	Deg. C	Control Room	0	0	0
143.1	Bulkhead Thermocouple	Deg. C	Torpedo Room	0	0	1.5
144.1	Bulkhead Thermocouple	Deg. C	Laundry	0	0	1.5
165.1	Oxygen	%	Laundry	0	0	0
166.1	Oxygen	%	Control Room	0	0	0
167.1	Oxygen	%	Control Room	0	0	0
168.1	Oxygen	%	Laundry	0	0	0
169.1	Carbon Dioxide	%	Control Room	0	0	0
170.1	Carbon Dioxide	%	Control Room	0	0	0
171.1	Carbon Dioxide	%	Laundry	0	0	0
172.1	Carbon Dioxide	%	Laundry	0	0	0
173.1	Carbon Monoxide	%	Control Room	0	0	0
174.1	Carbon Monoxide	%	Control Room	0	0	0
175.1	Carbon Monoxide	%	Laundry	0	0	0
176.1	Carbon Monoxide	%	Laundry	0	0	0
189.1	Logic	Volts	Laundry	0	0	0
44.2	Optical Density	% Transmission	Control Room	0	0	2.43
45.2	Optical Density	% Transmission	Control Room	0	0	1.55
46.2	Optical Density	% Transmission	Control Room	0	0	0.69
112.2	Deck Thermocouple	Deg. C	Control Room	0	0	0
113.2	Air Thermocouple	Deg. C	Control Room	0	0	0.05
114.2	Deck Thermocouple	Deg. C	Nav. Equip.	0	0	0
115.2	Air Thermocouple	Deg. C	Nav. Equip.	0	0	0.05
118.2	Deck Thermocouple	Deg. C	unknown	0	0	0
119.2	Air Thermocouple	Deg. C	unknown	0	0	0.05
120.2	Deck Thermocouple	Deg. C	Control Room	0	0	0
121.2	Air Thermocouple	Deg. C	Control Room	0	0	0.05
124.2	Air Thermocouple	Deg. C	Control Room	0	0	2.5
125.2	Air Thermocouple	Deg. C	Control Room	0	0	2
126.2	Air Thermocouple	Deg. C	Control Room	0	0	1.5
127.2	Air Thermocouple	Deg. C	Control Room	0	0	1
128.2	Air Thermocouple	Deg. C	Control Room	0	0	0.5
129.2	Air Thermocouple	Deg. C	Control Room	0	0	0.05

Table 5. (Continued)

Chan	Sensor	Units	Cmpt	X (m)	Y (m)	Z (m)
183.2	Radiometer	kW/m^2	Laundry	0	0	1
184.2	Calorimeter	kW/m^2	Laundry	0	0	1
185.2	Optical Density	% Transmission	Laundry Passageway	0	0	2.5
186.2	Optical Density	% Transmission	Laundry Passageway	0	0	1.5
187.2	Optical Density	% Transmission	Laundry Passageway	0	0	0.5

Table 5. (Continued)

APPENDIX A - Test Descriptions

Category	Code	Explanation
General		
	ND	No Data
	CD	Conflicting Data
	SD	Suspect Data
	NA	Not Applicable
	CR/WR	Connection between Control Room and Wardroom
	CS/CL	Connection between Combat Systems and Crew Living
	LP	Low Pressure
Compartments		
	LR	Laundry Room
	WR	Wardroom
	TR	Torpedo Room
	FE	Forward Escape Trunk
	CM	Crew Messroom
	CR	Control Room
	LR	Laundry Room
	CS	Combat Systems
	FR	Fan Room
	AMR	Auxiliary Machinery Room
Test Type		
	P	Preliminary (instrument calibration and setup)
	T	Test
	D	Demonstration
Fire Type		
	pan	Class B (diesel) pan fire
	crib	Class A (wood) crib fire
Fire Location		See Compartment codes
Fuel		
	PB	Particle Board
Fire Size		
	S	Small crib
	M	Medium crib
	L	Large crib
Hatches & Doors		
	O	Open
	C	Closed
	W	Closed with watertight door
	J	Closed with joiner door
	V	Variable - state changed during test
	SB	Closed with smoke blanket (hatches only)

Table A1. Key for interpreting the test description tables. ND (No Data) is used in cases where the paramter value was not recorded; CD (Conflicting Data) means that two or more parameter values were found in different sources; SD (Suspect Data) indicates that there was reason to believe that the parameter value was erroneous.

TEST			FIRE DESCRIPTION					
Num.	Type	Date	Type	Loc.	Fuel	Size (m)	m (kg/s) [x10-3]	Q (kW)
1-p1	P	06/10/1995	pan	LR	MeOH	0.90	5.6	116
1-p2	P	06/12/1995	pan	LR	MeOH	1.25	15.1	313
1-p3	P	06/12/1995	pan	LR	MeOH	1.25	17.3	360
1-p4	P	06/13/1995	pan	LR	MeOH	1.25	19.3	402
1-01	T	06/13/1995	pan	LR	diesel	0.68	4.8	192
1-02	T	06/14/1995	pan	LR	diesel	0.90	10.1	404
1-03	T	06/14/1995	pan	LR	diesel	1.05	SD	SD
1-04	T	06/15/1995	pan	LR	diesel	0.68	4.2	167
1-05	T	06/15/1995	pan	LR	diesel	0.68	SD	SD
1-06	T	06/16/1995	pan	LR	diesel	0.90	ND	ND
2-01	T	07/10/1995	pan	LR	diesel	0.90	10.2	408
2-02	T	07/10/1995	pan	LR	diesel	0.90	9.7	388
2-03	T	07/11/1995	pan	LR	diesel	1.25	14.0	ND
2-04	D	07/12/1995	pan	LR	diesel	1.25	21.5	859
2-05	D	07/13/1995	pan	LR	diesel	0.90	15.5	619
2-06	D	07/13/1995	pan	LR	diesel	0.90	ND	ND
3-01	T	08/16/1995	pan	LR	diesel	0.68	ND	ND
3-01A	T	08/17/1995	pan	LR	diesel	0.68	3.7	147
3-02	T	08/16/1995	pan	LR	diesel	0.90	9.5	381

Table A2. Test identification and fire description.

TEST			FIRE DESCRIPTION					
Num.	Type	Date	Type	Loc.	Fuel	Size (m)	m (kg/s) [x10-3]	Q (kW)
3-03	T	08/17/1995	pan	LR	diesel	1.05	12.0	480
3-04	T	08/18/1995	pan	LR	diesel	0.68	6.8	273
3-04A	T	08/18/1995	pan	LR	diesel	0.68	6.2	248
3-05	T	08/21/1995	pan	LR	diesel	0.68	6.9	275
3-06	T	08/21/1995	pan	LR	diesel	0.68	3.7	148
3-07	T	08/22/1995	pan	LR	diesel	1.05	ND	ND
3-08	T	08/22/1995	pan	LR	diesel	1.05	10.0	402
3-09	T	08/23/1995	pan	LR	diesel	0.68	7.2	288
3-10	T	08/23/1995	pan	LR	diesel	0.68	7.9	315
3-11	T	08/24/1995	pan	LR	diesel	0.68	7.2	289
3-11A	T	08/24/1995	pan	LR	diesel	0.68	ND	ND
3-12	T	08/24/1995	pan	LR	diesel	1.05	17.0	679
3-13	T	08/25/1995	pan	LR	diesel	1.05	12.8	512
3-14	T	08/25/1995	pan	LR	diesel	1.05	16.2	648
3-15	T	08/28/1995	pan	LR	diesel	0.68	8.0	320
3-16	T	08/28/1995	pan	LR	diesel	1.05	14.0	560
3-17	T	08/29/1995	pan	LR	diesel	1.05	12.6	504
3-18	T	08/29/1995	pan	LR	diesel	0.68	7.4	294
3-19	T	08/29/1995	pan	LR	diesel	0.68	10.3	412
3-20	T	08/30/1995	pan	LR	diesel	0.68	8.2	327
3-21	T	08/30/1995	pan	LR	diesel	0.68	7.0	281

Table A2. (Continued)

TEST			FIRE DESCRIPTION					
Num.	Type	Date	Type	Loc.	Fuel	Size (m)	m (kg/s) [x10-3]	Q (kW)
3-22	T	08/31/1995	pan	LR	diesel	0.68	8.4	337
3-23	T	08/31/1995	pan	LR	diesel	1.05	14.2	568
3-24	T	08/31/1995	pan	LR	diesel	1.05	SD	SD
3-25	T	09/05/1995	pan	LR	diesel	0.68	SD	SD
3-26	T	09/05/1995	pan	LR	diesel	0.68	11.2	450
3-27	T	09/05/1995	pan	LR	diesel	0.68	12.8	514
3-28	T	09/06/1995	pan	LR	diesel	0.68	7.5	300
3-29	T	09/06/1995	pan	LR	diesel	0.68	5.5	218
3-30	T	09/06/1995	pan	LR	diesel	0.68	7.9	315
4-01	T	01/24/1996	pan	LR	diesel	0.68	ND	ND
4-02	T	01/25/1996	pan	LR	diesel	0.68	9.2	367
4-03	T	01/25/1996	pan	LR	diesel	1.05	27.0	1080
4-04	T	01/26/1996	pan	LR	diesel	1.05	11.6	466
4-05	T	01/26/1996	pan	LR	diesel	1.05	32.7	1310
4-06	T	01/26/1996	pan	LR	diesel	1.05	27.6	1100
4-07	T	01/27/1996	pan	LR	diesel	1.05	30.9	1240
4-08	T	01/27/1996	pan	LR	diesel	1.05	22.5	901

Table A2. (Continued)

TEST			FIRE DESCRIPTION					
Num.	Type	Date	Type	Loc.	Fuel	Size (m)	m (kg/s) [x10-3]	Q (kW)
4-09	T	01/27/1996	pan	LR	diesel	1.05	24.6	984
4-10	T	01/29/1996	pan	LR	diesel	1.05	32.7	1310
4-11	T	01/30/1996	pan	WR	diesel	1.05	ND	ND
4-12	T	01/31/1996	pan	WR	diesel	0.68	ND	ND
4-13	T	01/31/1996	pan	WR	diesel	0.68	ND	ND
4-14	T	02/01/1996	pan	TR	diesel	0.68	ND	ND
4-15	T	02/01/1996	pan	TR	diesel	0.68	ND	ND
5-01	T	04/29/1996	pan	LR	diesel	0.68	6.7	248
5-02	T	05/01/1996	pan	LR	diesel	0.68	7.0	259
5-03	T	05/01/1996	pan	LR	diesel	0.68	5.9	219
5-04	T	05/01/1996	pan	LR	diesel	0.68	6.9	256
5-05	T	05/02/1996	pan	LR	diesel	0.68	6.4	237
5-06	T	05/02/1996	pan	LR	diesel	0.68	7.0	259
5-07	T	05/02/1996	pan	LR	diesel	0.68	7.1	263
5-08	T	05/03/1996	pan	FE	diesel	0.31	ND	ND
5-09	T	05/03/1996	pan	FE	diesel	0.31	ND	ND
5-10	T	05/03/1996	pan	CM	diesel	0.31	ND	ND
5-11	T	05/03/1996	pan	CM	diesel	0.31	ND	ND
5-12	T	05/03/1996	pan	TR	diesel	0.68	ND	ND
5-13	T	05/03/1996	pan	TR	diesel	0.68	ND	ND
5-14	T	05/04/1996	pan	LR	diesel	0.68	6.4	237
5-15	T	05/06/1996	pan	LR	diesel	0.68	ND	ND

Table A2. (Continued)

TEST			FIRE DESCRIPTION					
Num.	Type	Date	Type	Loc.	Fuel	Size (m)	m (kg/s) [x10-3]	Q (kW)
5-16	T	05/06/1996	pan	LR	diesel	0.68	4.8	178
5-17	T	05/06/1996	pan	LR	diesel	0.68	4.4	163
5-18	T	05/07/1996	pan	LR	diesel	0.68	6.0	222
5-19	T	05/07/1996	pan	LR	diesel	0.68	5.7	230
5-20	T	05/07/1996	pan	LR	diesel	0.68	8.1	322
5-21R	T	05/08/1996	pan	LR	diesel	0.68	3.5	130
5-22	T	05/09/1996	pan	LR	diesel	0.68	2.9	115
6-01	T	08/21/1996	pan	LR	diesel	0.31	2.2	89
6-02	T	08/21/1996	pan	LR	diesel	0.31	1.5	59
6-03	T	08/22/1996	pan	TR	diesel	0.31	ND	ND
6-04	T	08/22/1996	pan	TR	diesel	0.68	ND	ND
6-05	T	08/23/1996	pan	TR	diesel	0.31	ND	ND
6-06	T	08/23/1996	pan	TR	diesel	0.68	ND	ND
6-07	T	08/23/1996	pan	LR	diesel	0.31	ND	ND
6-08	T	08/24/1996	pan	LR	diesel	0.31	1.3	52
6-09	T	08/26/1996	crib	LR	wood	S	3.8	NA
6-10	T	08/26/1996	crib	LR	wood	L	SD	NA
6-11	T	08/26/1996	crib	LR	wood	L	19.8	NA
6-12	T	08/26/1996	crib	LR	wood	S	2.2	NA
6-13	T	08/27/1996	pan	TR	diesel	0.31	ND	ND
6-14	T	08/27/1996	crib	LR	wood + PB	M	ND	ND

Table A2. (Continued)

TEST			FIRE DESCRIPTION					
Num.	Type	Date	Type	Loc.	Fuel	Size (m)	m (kg/s) [x10-3]	Q (kW)
6-15	D	08/28/1996	pan	LR	diesel	0.68	2.4	95
6-16	D	08/28/1996	pan	LR	diesel	0.68	1.1	44
6-17	D	08/29/1996	pan	TR	diesel	0.31	ND	ND
6-18	D	08/29/1996	pan	LR	diesel	0.68	2.6	104
6-19	D	08/30/1996	crib	LR	wood +PB	M	ND	ND
6-20	T	08/30/1996	pan	LR	diesel	0.31	1.7	67
6-21	T	08/30/1996	pan	TR	diesel	0.31	ND	ND
6-22	T	08/30/1996	pan	TR	diesel	0.68	ND	ND

Table A2. (Continued)

TEST	HATCHES										DOORS										
Num.	Sail									Bilges											
	H01	H1	H2	H3	H4	H5	H6	H7	H8	H9-14	D1	D1'	D2	D3	D4	D5	D6	D7	D7'	D8	D9
1-p1	O	O	O	O	O	O	C	O	C	C	W	NA	O	O	O	O	O	O	NA	O	O
1-p2	O	O	O	O	O	O	C	O	C	C	W	NA	O	O	O	O	O	O	NA	O	O
1-p3	O	C	C	C	O	O	C	O	C	C	W	NA	O	O	O	O	O	O	NA	O	O
1-p4	O	C	C	C	O	O	C	O	C	C	W	NA	O	O	O	O	O	O	NA	O	O
1-01	O	O	O	O	O	O	C	O	C	C	C	NA	O	O	O	O	O	O	NA	O	O
1-02	O	O	O	O	O	O	C	O	C	C	W	NA	O	O	O	O	O	O	NA	O	O
1-03	O	O	O	O	O	O	C	O	C	C	W	NA	O	O	O	O	O	O	NA	O	O
1-04	O	C	C	C	O	O	C	O	C	C	W	NA	O	O	O	O	O	O	NA	O	O
1-05	O	O	O	O	O	O	C	O	C	C	W	NA	J	O	W	J	J	J	NA	J	J
1-06	O	O	O	O	O	O	C	O	C	C	W	NA	J	O	W	J	J	J	NA	J	J
2-01	O	O	O	O	O	O	C	O	C	C	W	ND	O	O	O	O	O	O	NA	O	O
2-02	O	O	O	O	O	O	C	O	O	C	W	ND	O	O	O	O	O	O	NA	O	O
2-03	O	C	C	C	O	O	C	O	O	C	W	ND	O	O	O	O	O	O	O	O	O
2-04	O	O	O	C	O	O	C	O	O	C	W	ND	O	O	O	O	O	O	O	O	O
2-05	I	C	C	C	O	O	C	O	O	C	CD	ND	O	O	O	O	O	O	O	O	O
2-06	O	V	V	C	V	O	C	O	O	C	V	V	O	O	O	O	O	O	O	O	O
3-01	C	C	C	C	O	O	C	O	O	C	W	ND	O	O	O	O	W	O	O	O	O
3-01A	C	C	C	C	O	O	C	O	O	C	W	CD	CD	O	CD	CD	CD	CD	O	CD	CD
3-02	C	C	C	C	O	O	C	O	O	C	W	CD	O	O	O	O	CD	O	O	O	O

Table A3. Description of hatches and door configuration.

TEST	HATCHES										DOORS										
Num.	Sail									Bilges											
	H01	H1	H2	H3	H4	H5	H6	H7	H8	H9-14	D1	D1'	D2	D3	D4	D5	D6	D7	D7'	D8	D9
3-03	C	C	C	C	O	O	C	O	O	C	W	CD	O	O	O	O	CD	O	O	O	O
3-04	O	O	O	O	O	O	C	O	O	C	CD	O	O	O	O	O	O	O	O	O	O
3-04A	O	O	O	O	O	O	C	O	O	C	W	CD	O	O	O	O	O	O	O	O	O
3-05	C	O	C	C	O	O	C	O	O	O	W	O	O	O	O	O	W	O	O	O	O
3-06	C	O	C	C	O	O	C	O	O	C	O	CD	J	O	W	J	W	J	O	J	J
3-07	C	C	C	C	O	O	C	O	O	C	W	CD	O	O	O	O	W	O	O	O	O
3-08	C	C	C	C	O	O	C	O	O	C	W	CD	J	CD	C	J	W	J	O	J	J
3-09	O	O	O	O	O	O	C	O	O	O	W	C	J	O	C	J	W	J	O	J	J
3-10	C	C	C	O	O	O	C	O	O	O	W	C	J	O	C	J	W	J	O	J	J
3-11	O	V	O	O	O	O	O	O	O	O	W	C	J	O	C	J	C	J	O	J	J
3-11A	V	O	C	O	O	O	C	O	O	O	W	C	J	O	C	J	C	J	O	J	J
3-12	C	O	C	O	O	O	C	O	O	O	W	C	J	O	C	J	C	J	O	J	J
3-13	C	O	C	C	O	O	C	O	O	C	W	C	J	CD	C	J	W	J	O	J	J
3-14	C	O	C	C	O	O	C	O	O	O	W	C	J	CD	C	J	W	J	O	J	J
3-15	C	O	C	C	O	O	C	O	O	O	W	C	J	CD	C	J	W	J	O	J	J
3-16	C	O	C	C	O	O	C	O	O	O	W	C	J	CD	C	J	W	J	O	J	J
3-17	C	O	O	C	O	O	C	O	O	O	W	C	J	CD	C	J	W	J	O	J	J
3-18	C	O	O	C	O	O	C	O	O	O	W	C	J	CD	C	J	W	J	O	J	J
3-19	V	O	O	C	O	O	C	O	O	O	W	C	J	CD	C	J	CD	J	O	J	J
3-20	C	O	C	O	O	O	C	O	O	O	W	C	J	O	C	J	W	J	O	J	J
3-21	V	O	C	O	O	O	C	O	O	O	W	C	J	O	W	J	CD	J	O	J	J

Table A3. (Continued)

TEST	HATCHES										DOORS										
Num.	Sail									Bilges											
	H01	H1	H2	H3	H4	H5	H6	H7	H8	H9-14	D1	D1'	D2	D3	D4	D5	D6	D7	D7'	D8	D9
3-22	C	O	C	O	O	O	C	O	O	O	W	C	J	O	W	J	W	J	O	J	J
3-23	C	O	C	C	O	O	C	O	O	O	W	C	J	O	W	J	W	J	O	J	J
3-24	C	O	C	C	O	O	C	O	O	C	W	C	J	O	W	J	W	J	O	J	J
3-25	V	O	C	O	O	O	C	O	O	O	W	C	J	O	W	J	W	V	O	J	J
3-26	V	O	C	O	O	O	C	O	O	O	W	C	J	O	W	J	W	V	O	J	J
3-27	V	O	O	C	O	O	O	O	O	O	W	C	J	O	W	J	W	V	O	J	J
3-28	V	O	C	O	SB	SB	C	SB	SB	O	W	C	J	O	W	J	W	J	O	J	J
3-29	V	O	C	O	SB	SB	C	SB	SB	O	W	C	J	O	W	J	W	J	O	J	J
3-30	C	O	C	C	SB	SB	C	SB	SB	O	W	C	J	O	W	J	CD	J	O	J	J
4-01	C	C	C	C	O	O	C	O	O	C	O	O	O	O	O	O	O	O	O	O	O
4-02	C	C	C	C	O	O	C	O	O	C	O	O	O	O	O	O	O	O	O	O	O
4-03	C	C	C	C	O	O	C	O	O	C	O	O	O	O	O	O	O	O	O	O	O
4-04	C	C	C	C	O	O	C	O	O	C	W	C	J	O	W	J	C	J	CD	J	J
4-05	C	C	C	C	O	O	C	O	O	O	O	O	O	O	O	O	O	O	O	O	O
4-06	C	C	C	C	O	O	C	O	O	O	O	O	O	O	O	O	O	O	O	O	O
4-07	C	C	C	C	O	O	C	O	O	C	O	O	O	O	O	O	O	O	O	O	O
4-08	C	C	C	C	O	O	C	O	O	O	W	C	J	O	W	J	C	J	CD	J	J

Table A3. (Continued)

TEST	HATCHES										DOORS										
Num.	Sail									Bilges											
	H01	H1	H2	H3	H4	H5	H6	H7	H8	H9-14	D1	D1'	D2	D3	D4	D5	D6	D7	D7'	D8	D9
4-09	C	C	C	C	O	O	C	O	O	C	W	C	J	O	W	J	C	J	ND	J	J
4-10	C	C	C	C	O	O	C	O	O	C	O	O	O	O	O	O	O	O	O	O	O
4-11	C	C	C	C	O	O	C	O	O	O	W	C	J	O	W	J	C	J	ND	J	J
4-12	C	C	C	C	O	O	C	O	O	O	W	C	J	O	W	J	C	J	ND	J	J
4-13	C	C	C	C	O	O	C	O	O	O	W	C	J	O	W	J	C	J	ND	J	J
4-14	C	C	C	C	O	O	C	O	O	O	W	C	J	O	W	J	C	J	ND	J	J
4-15	C	C	C	C	O	O	C	O	O	O	W	C	J	O	W	J	C	J	ND	J	J
5-01	ND	C	C	C	O	O	ND	O	O	O	ND	ND	ND	O	ND	ND	ND	ND	O	ND	J
5-02	ND	C	C	C	O	O	ND	O	O	O	ND	ND	ND	O	O	ND	ND	ND	O	ND	ND
5-03	C	O	C	O	O	O	C	O	O	O	W	C	J	O	O	J	C	J	O	J	J
5-04	C	O	O	O	O	O	C	O	O	O	W	C	J	O	O	J	C	J	O	J	J
5-05	C	O	O	V	O	O	C	O	O	O	W	C	J	O	O	J	C	J	O	J	J
5-06	O	O	O	O	O	O	C	O	O	O	W	C	J	O	O	J	C	J	O	J	J
5-07	O	O	C	O	O	O	C	O	O	O	W	C	J	O	O	J	C	J	O	J	J
5-08	O	O	C	O	O	O	C	O	O	O	W	C	J	O	O	J	C	J	O	J	J
5-09	C	O	O	O	O	O	C	O	O	O	W	C	J	O	O	J	C	J	O	J	J
5-10	C	O	O	O	O	O	C	O	O	O	W	C	J	O	O	J	C	J	O	J	J
5-11	O	O	C	O	O	O	C	O	O	O	W	C	J	O	O	J	C	J	O	J	J
5-12	O	O	C	O	O	O	C	O	O	O	W	C	J	O	O	J	C	J	O	J	J
5-13	C	O	O	O	O	O	C	O	O	O	W	C	J	O	O	J	C	J	O	J	J
5-14	C	C	C	O	O	O	C	O	O	O	W	O	J	O	O	J	C	J	O	J	J
5-15	V	O	C	C	O	O	C	O	O	O	W	O	J	O	O	J	C	C	O	J	J

Table A3. (Continued)

TEST	HATCHES										DOORS										
Num.	Sail									Bilges											
	H01	H1	H2	H3	H4	H5	H6	H7	H8	H9-14	D1	D1'	D2	D3	D4	D5	D6	D7	D7'	D8	D9
5-16	V	O	C	C	O	O	C	O	O	O	V	O	J	O	O	J	C	J	O	J	J
5-17	V	O	C	C	O	O	C	O	O	O	V	O	J	O	O	J	C	J	O	J	J
5-18	C	O	C	C	O	O	C	O	O	O	V	O	J	O	O	J	C	V	O	J	J
5-19	C	O	C	C	SB	O	C	O	O	O	V	O	J	O	O	J	C	J	O	J	J
5-20	C	O	C	C	O	O	C	O	O	O	W	C	J	O	O	J	C	J	O	J	J
5-21R	V	O	C	C	SB	SB	C	O	O	O	V	V	V	O	O	J	C	J	O	J	J
5-22	V	O	C	C	SB	SB	C	O	O	O	V	V	J	O	O	J	C	J	O	J	J
6-01	V	O	C	C	O	O	C	O	O	O	V	C	J	O	O	J	C	J	O	J	J
6-02	V	O	C	C	O	O	C	O	O	O	V	O	J	O	O	J	C	J	O	J	J
6-03	V	O	C	C	O	O	C	O	O	O	V	O	J	O	O	J	C	J	O	J	J
6-04	V	O	C	C	O	O	C	O	O	O	V	O	J	O	O	J	C	J	O	J	J
6-05	V	O	C	C	O	O	C	O	O	O	V	O	J	O	O	J	C	J	O	J	J
6-06	V	O	C	C	O	O	C	O	O	O	V	O	J	O	O	J	C	J	O	J	J
6-07	V	O	C	C	O	O	C	O	O	O	V	O	J	O	O	J	C	J	O	J	J
6-08	V	O	C	C	O	O	C	O	O	O	V	O	J	O	O	J	C	J	O	J	J
6-09	C	O	C	C	O	O	C	O	O	O	W	C	J	O	O	J	C	J	O	J	J
6-10	C	O	C	C	O	O	C	O	O	O	W	C	J	O	O	J	C	J	O	J	J
6-11	O	O	O	O	O	O	C	O	O	O	W	C	J	O	O	J	C	J	O	J	J
6-12	O	O	O	O	O	O	C	O	O	O	W	C	J	O	O	J	C	J	O	J	J
6-13	V	O	C	C	O	O	C	O	O	O	W	O	J	O	O	J	C	V	O	J	J
6-14	C	O	C	C	O	O	C	O	O	O	W	C	J	O	O	J	C	J	O	J	J

Table A3. (Continued)

TEST	HATCHES										DOORS										
Num.	Sail									Bilges											
	H01	H1	H2	H3	H4	H5	H6	H7	H8	H9-14	D1	D1'	D2	D3	D4	D5	D6	D7	D7'	D8	D9
6-15	C	O	C	C	O	O	C	O	O	O	ND	ND	ND	ND	ND	ND	ND	ND	O	ND	ND
6-16	ND	ND	C	O	O	O	C	O	O	O	ND	ND	ND	O	ND	ND	ND	ND	O	ND	ND
6-17	ND	ND	C	C	O	O	C	O	O	O	O	ND	ND	ND	ND	ND	ND	ND	O	ND	J
6-18	ND	ND	C	C	O	O	C	O	O	O	O	ND	ND	ND	ND	ND	ND	ND	O	ND	ND
6-19	O	O	O	O	O	O	C	O	O	O	W	C	J	O	O	J	C	J	O	J	J
6-20	V	O	C	C	O	O	C	O	O	O	V	O	J	O	O	J	C	J	O	J	J
6-21	V	O	C	C	O	O	C	O	O	O	V	O	J	O	O	J	C	J	O	J	J
6-22	V	O	C	C	O	O	C	O	O	O	V	O	J	O	O	J	C	J	O	J	J

Table A3. (Continued)

TEST	CONFIGURATION MODIFICATIONS						VENTILATION									REMARKS
Num.	Part.		Trunk Ext.	Frame Bays			Initial		Smoke Blankets	Ind. System	FR/ AMR Diesel	LP Blower	Pos. Press.			
	CR	LR		CR/ WR	CS/ CL	Ducts	Mode	Secure					CR	CS		
1-p1	NA	NA	no	NA	NA	NA	recirc.	+1	no	off	NA	off	no	no	Instrumentation tests.
1-p2	NA	NA	no	NA	NA	NA	recirc.	+1	no	off	NA	off	no	no	Instrumentation tests.
1-p3	NA	NA	NA	NA	NA	NA	recirc.	+1	no	off	NA	off	no	no	Instrumentation tests.
1-p4	NA	NA	NA	NA	NA	NA	recirc.	+1	no	off	NA	off	no	no	Instrumentation tests
1-01	NA	NA	no	NA	NA	NA	recirc.	+1	no	off	NA	off	no	no	Effects of fire size, open boat. Burp @ ~+20:00.
1-02	NA	NA	no	NA	NA	NA	recirc.	+1	no	off	NA	off	no	no	Effects of fire size, open boat.
1-03	NA	NA	no	NA	NA	NA	recirc.	+1	no	off	NA	off	no	no	Effects of fire size, open boat.
1-04	NA	NA	NA	NA	NA	NA	recirc.	+1	no	off	NA	off	no	no	Effects of fire size, open boat. Comment illegible.
1-05	NA	NA	no	NA	NA	NA	recirc.	+1	no	off	NA	off	no	no	Effects of joiner doors, open boat.
1-06	NA	NA	no	NA	NA	NA	recirc.	+1	no	off	NA	off	no	no	Comments illegible.
2-01	yes	NA	no	NA	NA	NA	recirc.	+1	no	off	NA	off	no	no	Effects of CR partition.
2-02	yes	NA	no	NA	NA	NA	recirc.	+1	no	off	NA	off	no	no	Effects of opening H8. Same as 2-01, except H8.
2-03	yes	yes	NA	NA	NA	NA	recirc.	+1	no	off	NA	off	no	no	Effects of LR partition.
2-04	yes	yes	NA	NA	NA	NA	recirc.	+1	no	off	NA	off	no	no	TYCOM demo open boat w/observers. Biflow probes moved-data invalid.
2-05	yes	yes	NA	NA	NA	NA	recirc.	+1	no	off	NA	off	no	no	TYCOM demo closed boat w/observers. Biflow probes moved-data invalid. Checklist partially illegible.
2-06	yes	yes	NA	NA	NA	NA	recirc.	+1:27	V	V	NA	V	no	no	TYCOM demo, active ventilation, multiple hatch configs. Biflow probes moved-data invalid.
3-01	yes	yes	NA	NA	NA	NA	recirc.	+1	no	off	NA	off	no	no	Deck 2, Fr 74 - CPO Living isolated due to leaks.
3-01A	yes	yes	NA	NA	NA	NA	recirc.	+1	no	off	NA	off	no	no	Effects of fire size closed boat baseline. Repeat 3-01.
3-02	yes	yes	NA	NA	NA	NA	recirc.	+1	no	off	NA	off	no	no	Effects of fire size closed boat baseline

Table A4. Modifications to the test facility, ventilation settings and special notes.

TEST	CONFIGURATION MODIFICATIONS						VENTILATION									REMARKS
Num.	Part.		Trunk Ext.	Frame Bays			Initial		Smoke Blankets	Ind. System	FR/ AMR Diesel	LP Blower	Pos. Press.			
	CR	LR		CR/ WR	CS/ CL	Ducts	Mode	Secure						CR	CS	
3-03	yes	yes	NA	NA	NA	NA	recirc.	+1	no	off	NA	off	no	no	Effects of fire size; closed boat baseline
3-04	yes	yes	no	NA	NA	NA	recirc.	+1	no	off	NA	off	no	no	W/o trunk extension; open boat
3-04A	yes	yes	yes	NA	NA	NA	recirc.	+1	no	off	NA	off	no	no	W/ trunk extension; open boat
3-05	yes	yes	NA	NA	NA	NA	recirc.	+1	no	off	NA	off	no	no	Effect of bilges? 3-01 except bilges open? H1 discrepancy. Closed boat.
3-06	yes	yes	NA	NA	NA	NA	recirc.	+1	no	off	NA	off	no	no	Effect of joiner doors? Previous tests used WTDs? Closed boat.
3-07	yes	yes	NA	NA	NA	NA	recirc.	+1	no	off	NA	off	no	no	Effects of open bilges w/ large fires. Closed boat.
3-08	yes	yes	NA	NA	NA	NA	recirc.	+1	no	off	NA	off	no	no	Effects of joiner doors? Closed boat. Larger fire size & interior partitions.
3-09	yes	yes	yes	NA	NA	NA	recirc.	+1	no	off	NA	off	no	no	Effects of hatch openings. Escape trunk extension.
3-10	yes	yes	yes	NA	NA	NA	recirc.	+1	no	off	NA	off	no	no	Effects of hatch openings.
3-11	yes	yes	yes	NA	NA	NA	recirc.	+1	no	off	NA	off	no	no	Effects of hatch openings. Aborted due to full computer disk.
3-11A	yes	yes	yes	NA	NA	NA	recirc.	+1	no	off	NA	off	no	no	Repeat 3-11? H01/H1 & H6 discrepancies.
3-12	yes	yes	yes	NA	NA	NA	recirc.	+1	no	off	NA	off	no	no	Effects of hatch openings. Repeat 3-10 w/ larger fire. H1 discrepancy.
3-13	yes	yes	NA	NA	NA	NA	recirc.	+1	no	off	NA	off	no	no	Effects of open bilges. Effects of joiner doors? Closed boat.
3-14	yes	yes	NA	NA	NA	NA	recirc.	+1	no	off	NA	off	no	no	Effects of bilges. Compare 3-13.
3-15	yes	yes	NA	O	NA	no	recirc.	+1	no	off	NA	off	no	no	Effects of fire size closed boat; open frame bays.
3-16	yes	yes	NA	O	NA	no	recirc.	+1	no	off	NA	off	no	no	Effects of fire size; closed boat; open frame bays.
3-17	yes	yes	NA	O	NA	no	recirc.	+1	no	off	NA	off	no	no	Effects of H2 openings; open frame bays.
3-18	yes	yes	NA	O	NA	no	recirc.	+1	no	off	NA	off	no	no	Effects of hatch openings; open frame bays. Effects of fire size. Compare 3-17.
3-19	yes	yes	NA	O	NA	no	recirc.	+1	no	off	NA	off	no	no	Effects of H01/H1 openings; open frame bays. Compare 3-18.
3-20	yes	yes	yes	O	NA	no	recirc.	+1	no	off	NA	off	no	no	Effects of H3 openings; open frame bays
3-21	yes	yes	yes	O	NA	no	recirc.	+1	no	off	NA	off	no	no	Effects of hatch openings; open frame bays.

Table A4. (Continued)

TEST	CONFIGURATION MODIFICATIONS						VENTILATION									REMARKS
Num.	Part.		Trunk Ext.	Frame Bays			Initial		Smoke Blankets	Ind. System	FR/ AMR Diesel	LP Blower	Pos. Press.			
	CR	LR		CR/ WR	CS/ CL	Ducts	Mode	Secure					CR	CS	
3-22	yes	yes	yes	O	NA	WR	recirc.	+1	no	off	NA	off	no	no	Effects of hatch openings; open frame bays; temp. frame bay ducts. Repeat 3-20?
3-23	yes	yes	NA	O	NA	no	recirc.	+1	no	off	NA	off	no	no	Repeat 3-22.
3-24	yes	yes	NA	O	NA	no	recirc.	+1	no	off	NA	off	no	no	Effects of joiner doors? Closed boat. Repeat 3-23.
3-25	yes	yes	yes	C	NA	no	recirc.	+1	no	off	V	off	no	no	Diesel extraction scenario. Active ventilation.
3-26	yes	yes	yes	O	NA	no	recirc.	+1	no	off	V	off	no	no	Diesel extraction scenario. Active ventilation.
3-27	yes	yes	NA	O	NA	no	recirc.	+1	no	off	V	off	no	no	Diesel extraction scenario w/ H3 closed. Active ventilation.
3-28	yes	yes	yes	O	NA	no	all off	NA	yes	off	off	off	no	no	Effects of smoke blankets; open boat; open frame bays.
3-29	yes	yes	yes	C	NA	no	all off	NA	yes	off	off	off	no	no	Effects of smoke blankets; open boat; closed frame bays. Compare 3-28.
3-30	yes	yes	NA	O	NA	no	all off	NA	yes	off	off	off	no	no	Effects of smoke blankets; closed boat; open frame bays.
4-01	yes	yes	NA	C	C	no	recirc.	+1	no	off	off	off	no	no	Repeat series 3 baseline; closed boat; small fire. Fans not shut down per schedule?
4-02	yes	yes	NA	C	C	no	recirc.	+1	no	off	off	off	no	no	Repeat 4-01
4-03	yes	yes	NA	C	C	no	recirc.	+1	no	off	off	off	no	no	Repeat baseline; closed boat; large fire.
4-04	yes	yes	NA	C	C	no	recirc.	+1	no	off	off	off	no	no	Baseline closed boat + joiner doors; Repeat 4-03? (doors are different) Questionable circumstances remain (test area vacuum, hi O2 in LR)
4-05	yes	yes	NA	C	C	no	recirc.	+1	no	off	off	off	no	no	Baseline + bilge; large fire
4-06	yes	yes	NA	O	O	no	recirc.	+1	no	off	off	off	no	no	Baseline + frame bays + bilges; large fire
4-07	yes	yes	NA	O	O	no	recirc.	+1	no	off	off	off	no	no	Baseline + frame bays; large fire
4-08	yes	yes	NA	O	O	no	recirc.	+1	no	off	off	off	no	no	Baseline + frame bays + joiner doors + bilges; large fire

Table A4. (Continued)

TEST	CONFIGURATION MODIFICATIONS						VENTILATION									REMARKS
Num.	Part.		Trunk Ext.	Frame Bays			Initial		Smoke Blankets	Ind. System	FR/ AMR Diesel	LP Blower	Pos. Press.			
	CR	LR		CR/ WR	CS/ CL	Ducts	Mode	Secure					CR	CS		
4-09	yes	yes	NA	O	O	no	recirc.	+1	no	off	off	off	no	no	Baseline + frame bays + joiner doors; large fire
4-10	yes	yes	NA	C	C	no	all off	NA	no	off	off	off	no	no	Modeling test - Vent ducting isolated frm remaining test area by blankoffs at terminals
4-11	yes	yes	NA	C	C	no	recirc.	+1	no	off	off	off	no	no	Baseline closed boat w/o frame bays; large fire; WR
4-12	yes	yes	NA	O	O	no	recirc.	+1	no	off	off	off	no	no	Baseline closed boat w/frame bays; small fire; WR
4-13	yes	yes	NA	C	C	no	recirc.	+1	no	off	off	off	no	no	Baseline closed boat w/o frame bays; small fire; WR
4-14	yes	yes	NA	C	C	no	recirc.	+1	no	off	off	off	no	no	Baseline closed boat w/o frame bays; small fire; TR
4-15	yes	yes	NA	O	O	no	recirc.	+1	no	off	off	off	no	no	Baseline closed boat w/ frame bays; small fire; TR
5-01	yes	yes	NA	O	O	yes	ND	ND	ND	ND	off	ND	no	no	Effect of induction valve closed. Checklist missing.
5-02	yes	yes	NA	O	O	yes	ND	ND	ND	ND	off	ND	no	no	Effect of induction valve open. Checklist missing.
5-03	yes	yes	yes	O	O	yes	recirc.	+1	no	on	off	ND	no	no	Effect of induction valve open. H3 open.
5-04	yes	yes	yes	O	O	yes	recirc.	+1	no	on	off	off	no	no	Effects of H2 & H3 open.
5-05	yes	yes	yes	O	O	yes	recirc.	+1	no	on	off	off	no	no	Effects of sequencing H3 opening
5-06	yes	yes	yes	O	O	yes	recirc.	+1	no	on	off	off	no	no	Effects of H1-H3 open.
5-07	yes	yes	yes	O	O	yes	recirc.	+1	no	on/off	off	off	no	no	Effect of H1 & H3. Fuel-controlled mass-loss test.
5-08	yes	yes	yes	O	O	yes	recirc.	+1	no	on	off	off	no	no	FE fire; effects of H1 & H3 open.
5-09	yes	yes	yes	O	O	yes	recirc.	+1	no	off	off	off	no	no	FE fire; effects of H2 & H3 open.
5-10	yes	yes	yes	O	O	yes	recirc.	+1	no	on	off	off	no	no	CM fire; effects of H2 & H3 open.
5-11	yes	yes	yes	O	O	yes	recirc.	+1	no	on	off	off	no	no	CM fire; effects at H1 & H3 open.
5-12	yes	yes	yes	O	O	yes	recirc.	+1	no	on	off	off	no	no	TR fire; H1 & H3 open
5-13	yes	yes	yes	O	O	yes	recirc.	+1	no	on	off	off	no	no	TR fire; H3 open.
5-14	yes	yes	yes	O	O	yes	recirc.	+1	no	on	off	on	no	no	Snorkel exhaust (LP blower test).
5-15	yes	yes	NA	O	O	yes	recirc.	+1	no	off	off	V	no	no	LP Blower exhaust, 15 min. pre-burn.

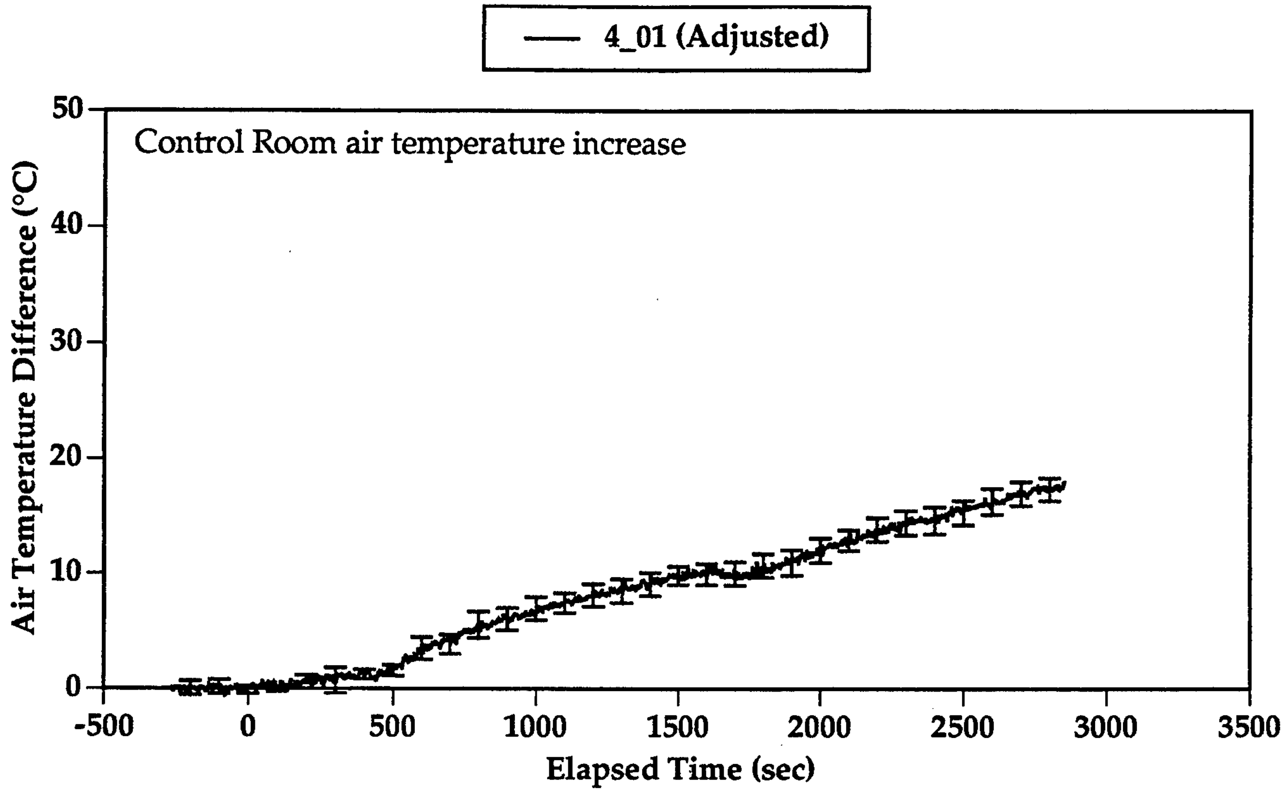
Table A4. (Continued)

TEST	CONFIGURATION MODIFICATIONS						VENTILATION								REMARKS
Num.	Part.		Trunk Ext.	Frame Bays			Initial		Smoke Blankets	Ind. System	FR/ AMR Diesel	LP Blower	Pos. Press.		
	CR	LR		CR/ WR	CS/ CL	Ducts	Mode	Secure					CR	CS	
5-16	yes	yes	NA	O	O	yes	recirc.	+1	no	V	off	ND	no	no	LP Blower exhaust, 17:14 min. pre-burn.
5-17	yes	yes	NA	O	O	yes	recirc.	+1	no	off	V	V	no	no	LP Blower & FR exhaust, 15 min. pre-burn.
5-18	yes	yes	NA	O	O	yes	recirc.	+1	no	V	V	V	no	no	10 min. pre-burn.
5-19	yes	yes	NA	O	O	yes	recirc.	+1	yes	off	V	off	yes	no	CR pressurization test.
5-20	yes	yes	NA	O	O	yes	none	NA	no	off	off	off	yes	yes	CR & CS pressurization test. Exhaust dampers open.
5-21R	yes	yes	NA	C	O	yes	recirc.	+1	yes	off	V	V	no	no	Effect of smoke stops & blankets, 15 min. pre-burn. Repeat 5-21.
5-22	yes	yes	NA	C	O	yes	recirc.	+1	yes	V	off	off	no	no	Effect of smoke stops & blankets, 15 min. pre-burn
6-01	yes	yes	NA	O	O	yes	recirc.	+1	no	off	V	V	no	no	Test plan #2.
6-02	yes	yes	NA	O	O	yes	recirc.	+1	no	off	V	V	no	no	Repeat 6-01 w/ D1' open.
6-03	yes	yes	NA	O	O	yes	recirc.	+1	no	off	V	V	no	no	Test plan #4.
6-04	yes	yes	NA	O	O	yes	recirc.	+1	no	off	V	V	no	no	Test plan #6. Repeat 6-03 w/ larger fire.
6-05	yes	yes	NA	O	O	yes	recirc.	+1	no	V	off	off	no	no	Test plan #3. 15 min. pre-burn.
6-06	yes	yes	NA	O	O	yes	recirc.	+1	no	V	off	off	no	no	Test plan #5. Repeat 6-05 w/ larger fire. 15 min. pre-burn.
6-07	yes	yes	NA	O	O	yes	recirc.	+1	no	V	off	off	no	no	Test plan #1. Repeat 6-05 w/ LR fire. 15 min. pre-burn.
6-08	yes	yes	NA	O	O	yes	recirc.	+1	no	V	off	off	no	no	Test plan #1. Repeat 6-07. 15 min. pre-burn.
6-09	yes	yes	NA	O	O	yes	recirc.	+1	no	off	off	off	no	no	Class A small fire; closed boat baseline.
6-10	yes	yes	NA	O	O	yes	recirc.	+1	no	off	off	off	no	no	Class A large fire; closed boat baseline.
6-11	yes	yes	yes	O	O	yes	recirc.	+1	no	off	off	off	no	no	Class A large fire; open boat baseline.
6-12	yes	yes	yes	O	O	yes	recirc.	+1	no	off	off	off	no	no	Class A small fire; open boat baseline.
6-13	yes	yes	NA	O	O	yes	recirc.	+1	no	V	V	V	no	no	Snorkel depth, active ventilation
6-14	yes	yes	NA	O	O	yes	recirc.	+1	no	off	off	off	no	no	Class A; closed boat. Wt. gain on load cell.

Table A4. (Continued)

TEST	CONFIGURATION MODIFICATIONS						VENTILATION									REMARKS
Num.	Part.		Trunk Ext.	Frame Bays			Initial		Smoke Blankets	Ind. System	FR/ AMR Diesel	LP Blower	Pos. Press.		
	CR	LR		CR/ WR	CS/ CL	Ducts	Mode	Secure					CR	CS	
6-15	yes	yes	NA	O	O	yes	recirc.	+1	no	off	off	off	no	no	Baseline closed boat demo. Checklist missing.
6-16	yes	yes	yes	O	O	yes	recirc.	+1	no	off	off	off	no	no	Effects of H1 & H3; in-port demo. Checklist missing.
6-17	yes	yes	NA	O	O	yes	recirc.	+1	no	off	on	on	no	no	At-sea active venting demo. Checklist missing.
6-18	yes	yes	NA	C	O	yes	recirc.	+1	yes	off	on	on	no	no	At-sea active venting demo w/smoke stops. Checklist missing.
6-19	yes	yes	yes	O	O	yes	recirc.	+1	no	off	off	off	no	no	Natural ventilation effects, open boat demo. Wt. gain on load cell.
6-20	yes	yes	NA	O	O	yes	recirc.	+1	no	off	V	V	no	no	Test plan #2. Repeat 6-02 (underway diesel exhaust). 15 min. pre-burn.
6-21	yes	yes	NA	O	O	yes	recirc.	+1	no	off	V	V	no	no	Effects of TR fire; 15 min. pre-burn. Repeat 6-03. Load cell noisy.
6-22	yes	yes	NA	O	O	yes	recirc.	+1	no	off	V	V	no	no	Test plan #6. Effects of large TR fire; 15 min. pre-burn. Repeat 6-04. Load cell noisy.

Table A4. (Continued)



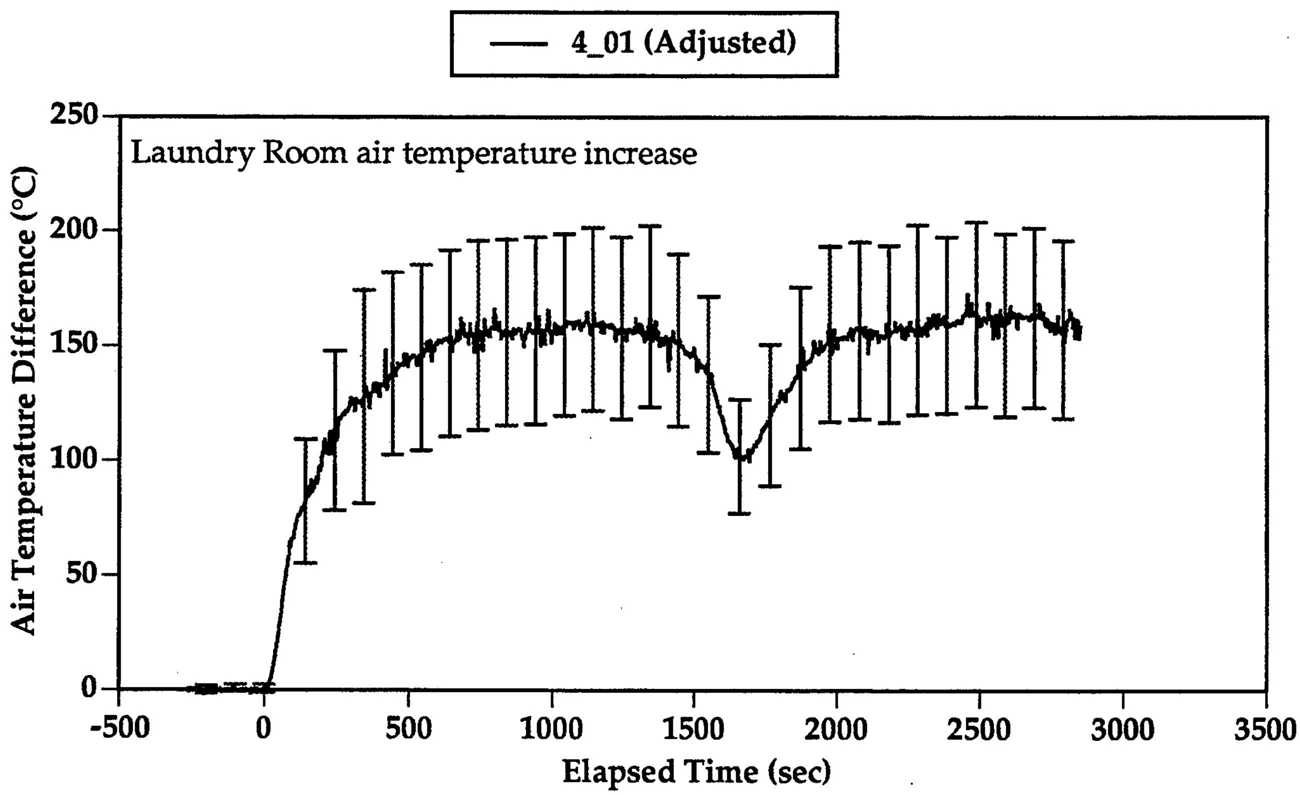


Figure B1. Temperature increase in Control Room and Laundry Room for Test 4_01 with data gap removed. Error bars are one standard deviation.

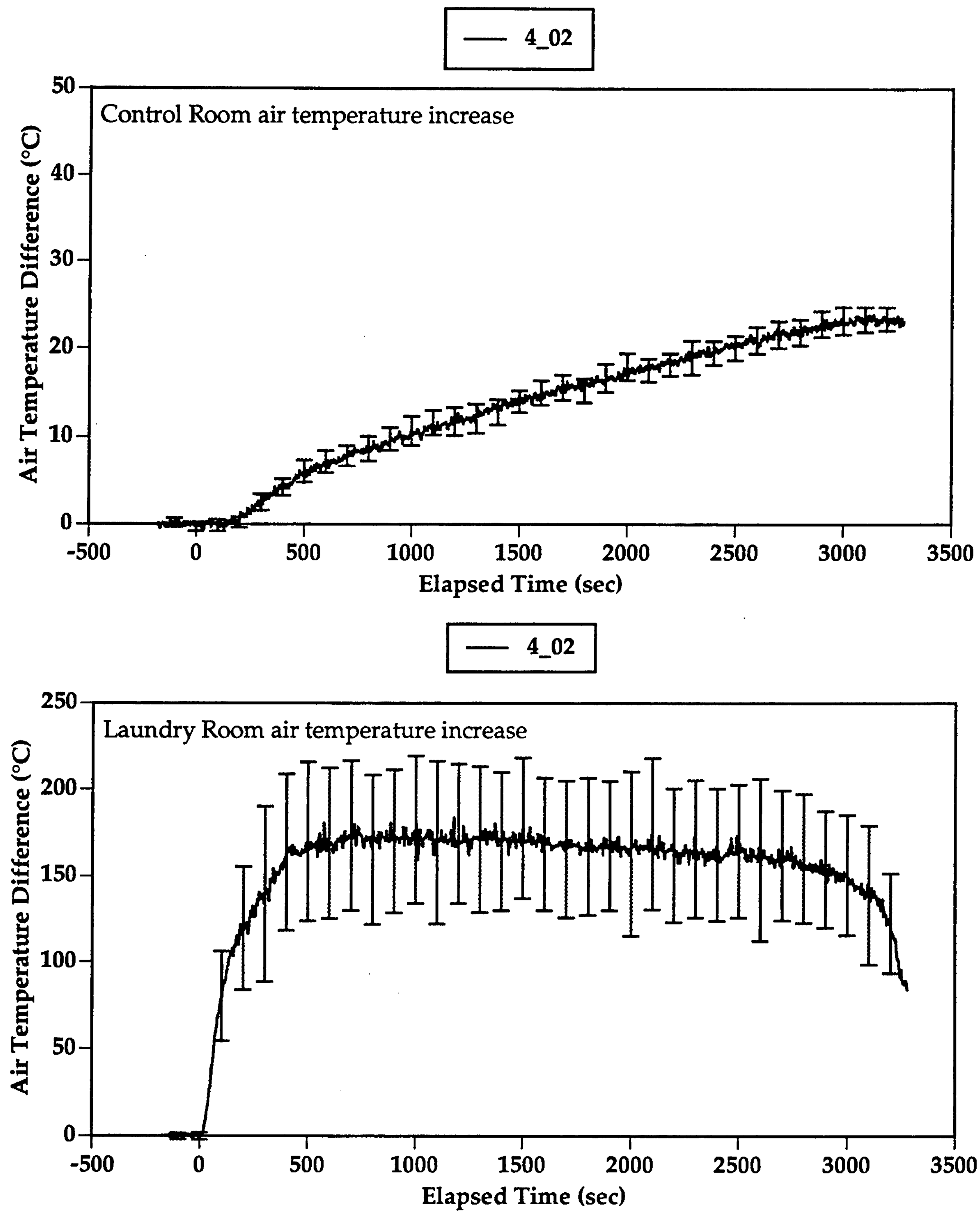
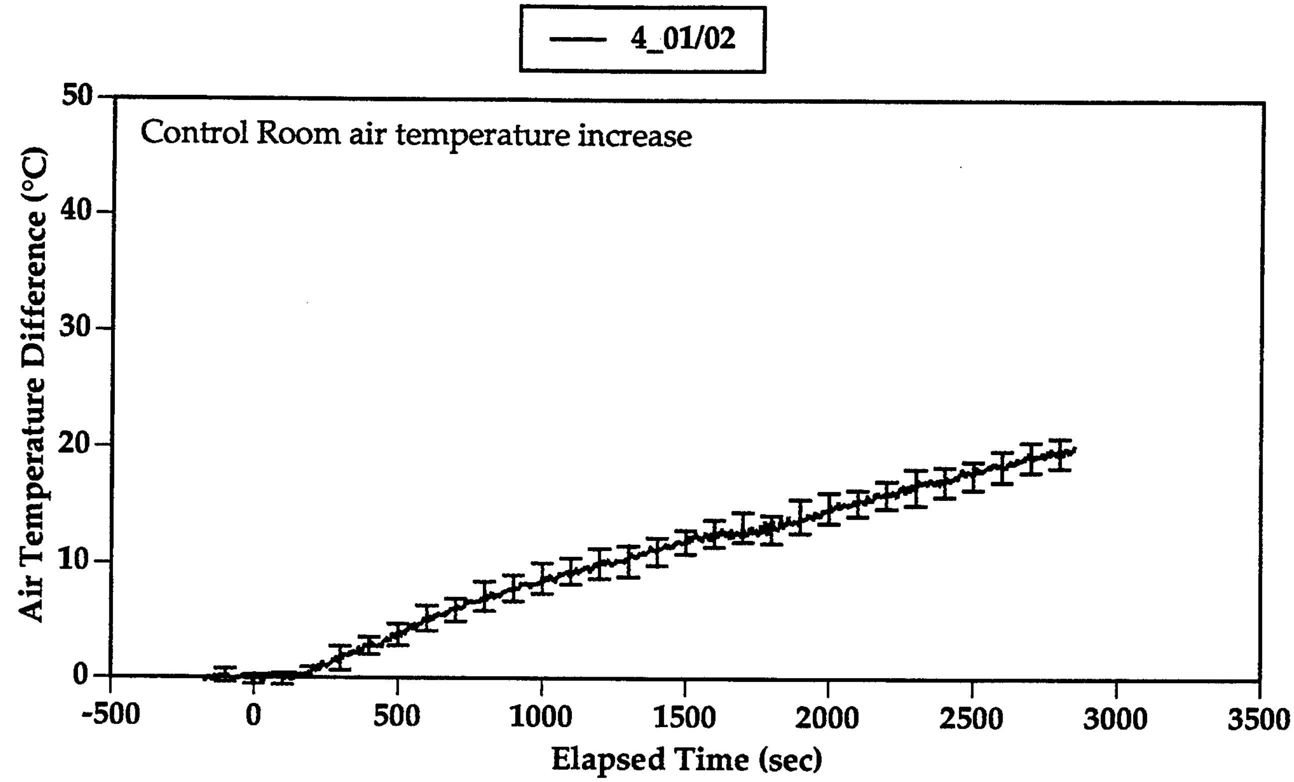


Figure B2. Temperature increase in Control Room and Laundry Room for Test 4_02. Error bars are one standard deviation.



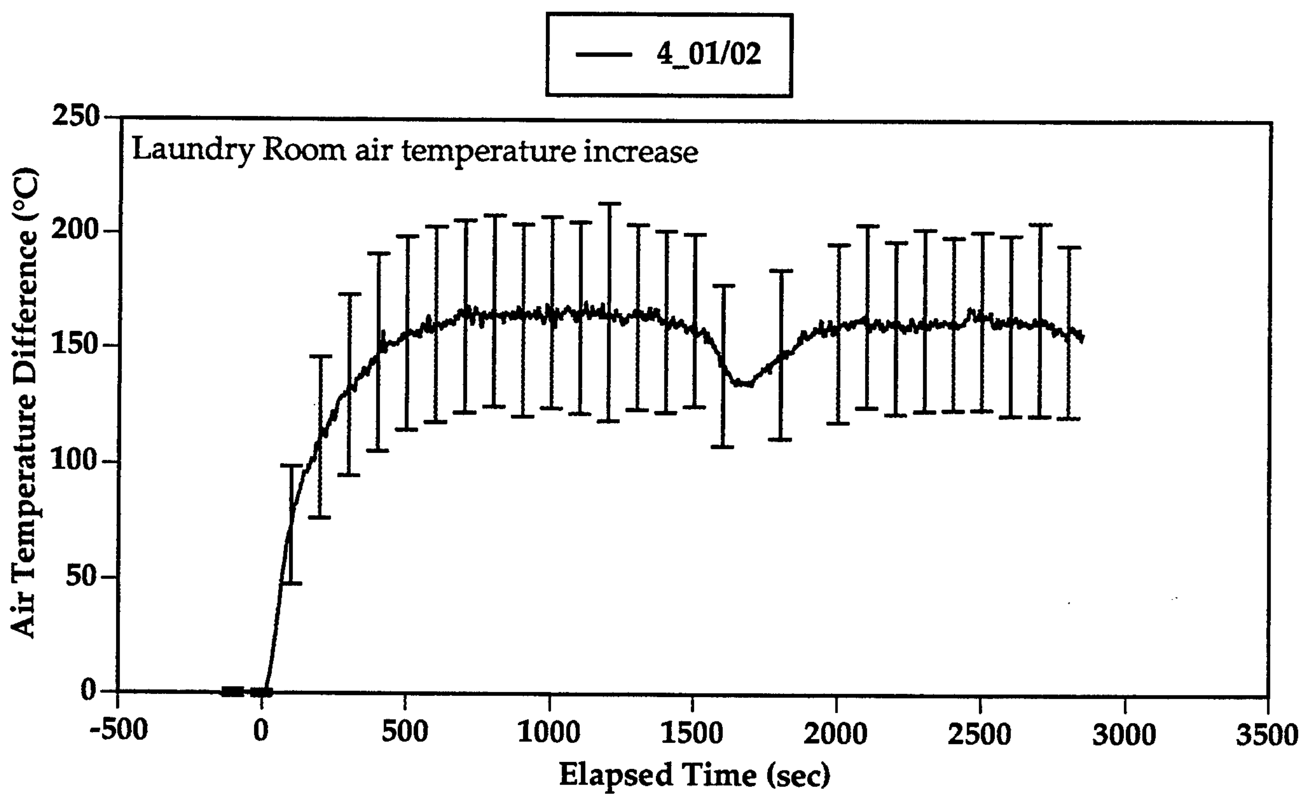
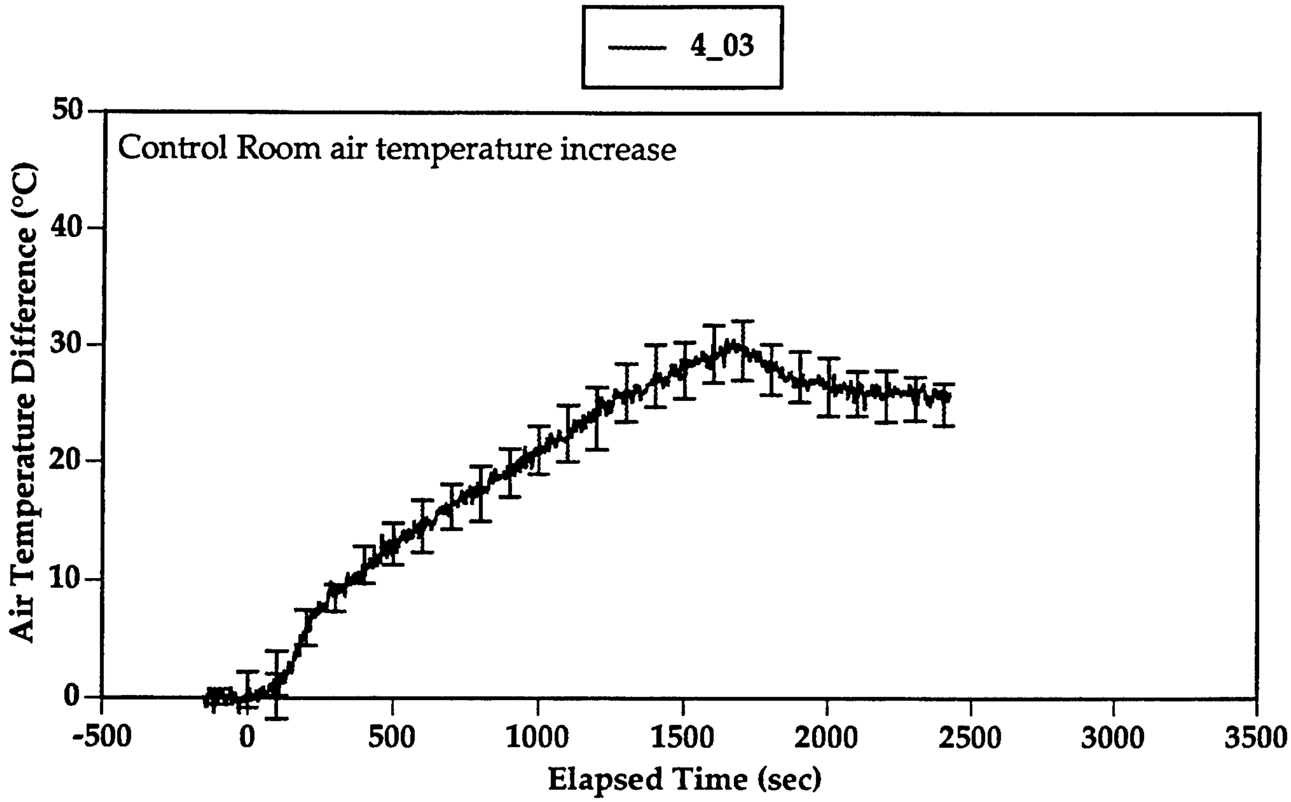


Figure B3. Temperature increase in Control Room and Laundry Room for Tests 4_01 and 4_02 combined. Error bars are one standard deviation.



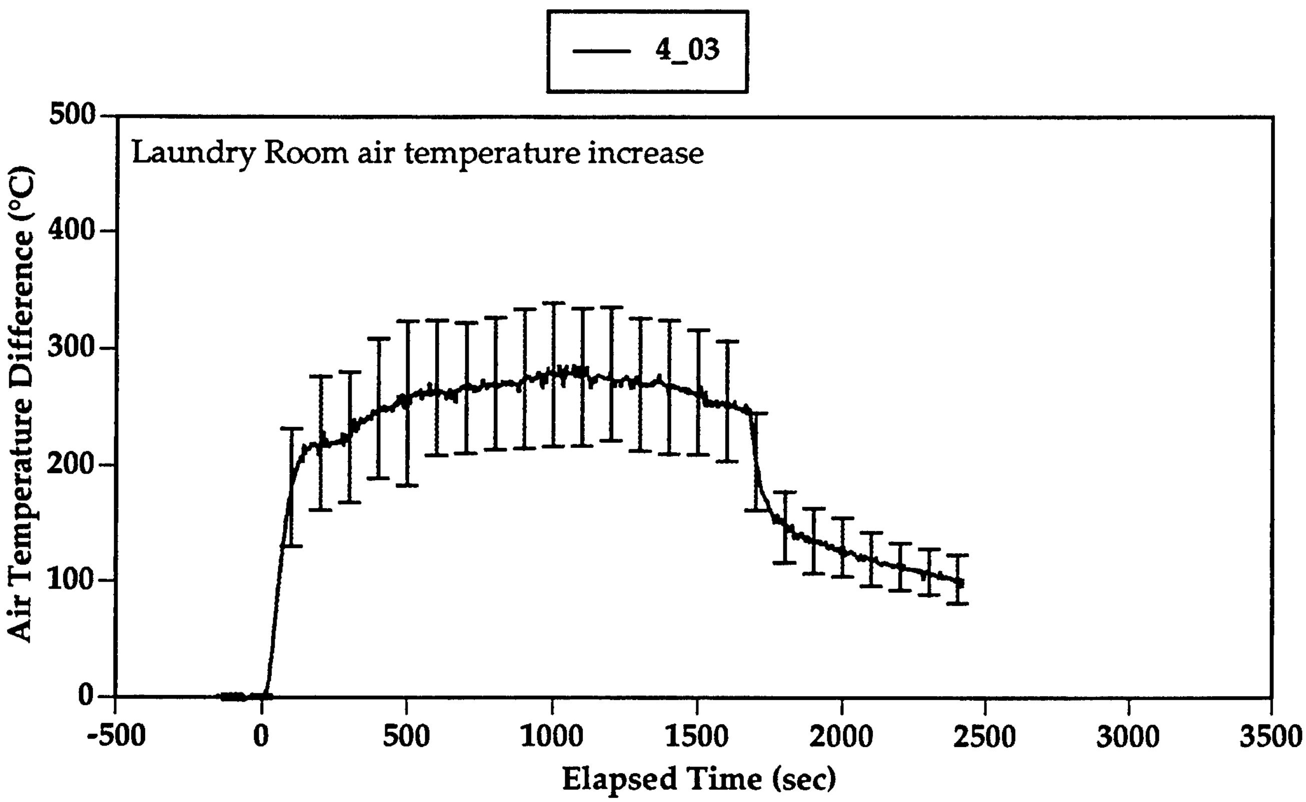
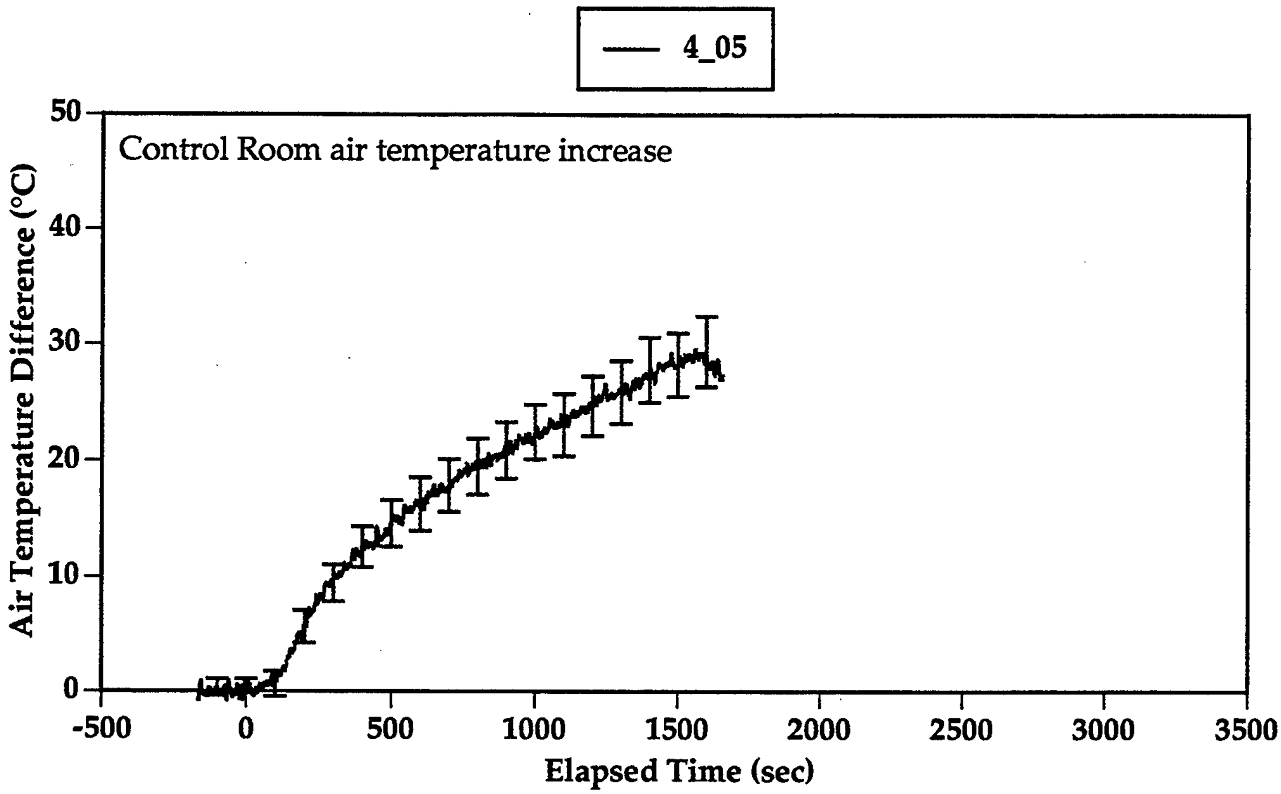


Figure B4. Temperature increase in Control Room and Laundry Room for Test 4_03. Error bars are one standard deviation.



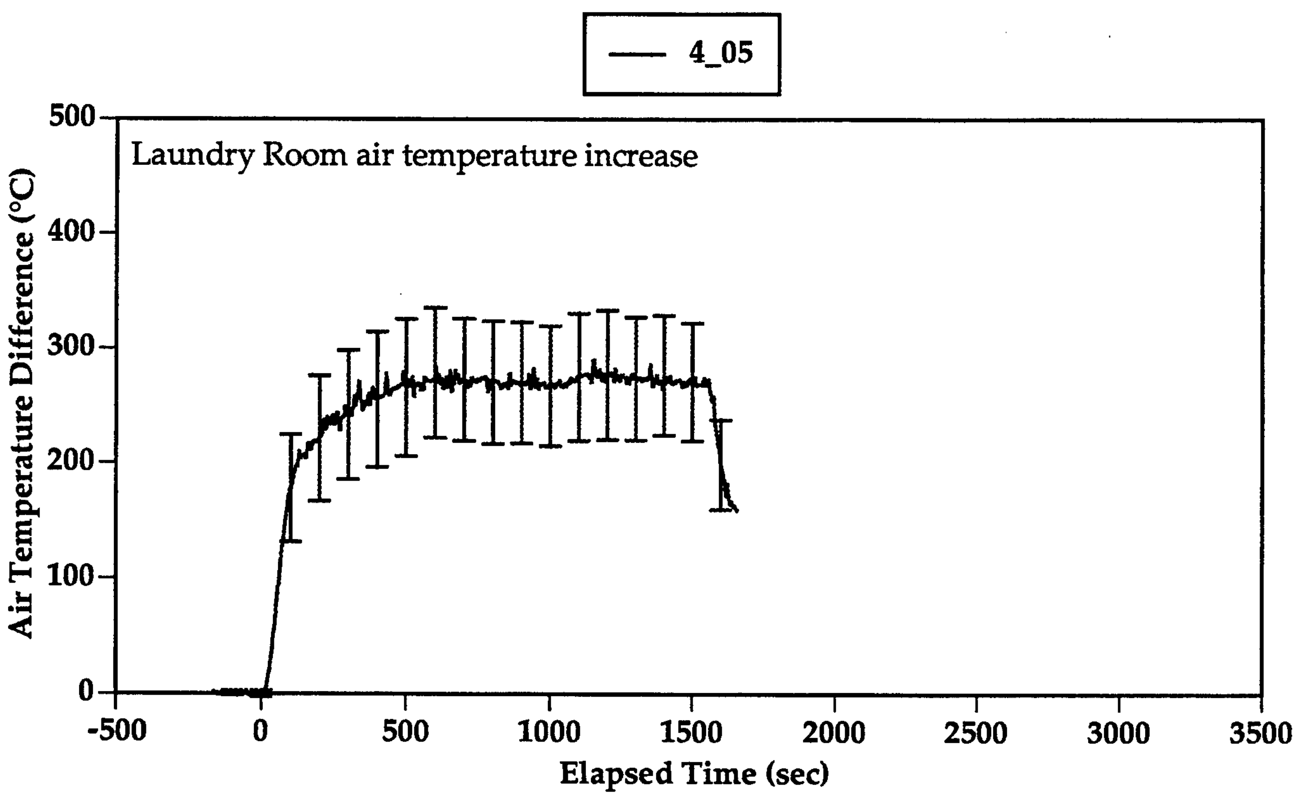
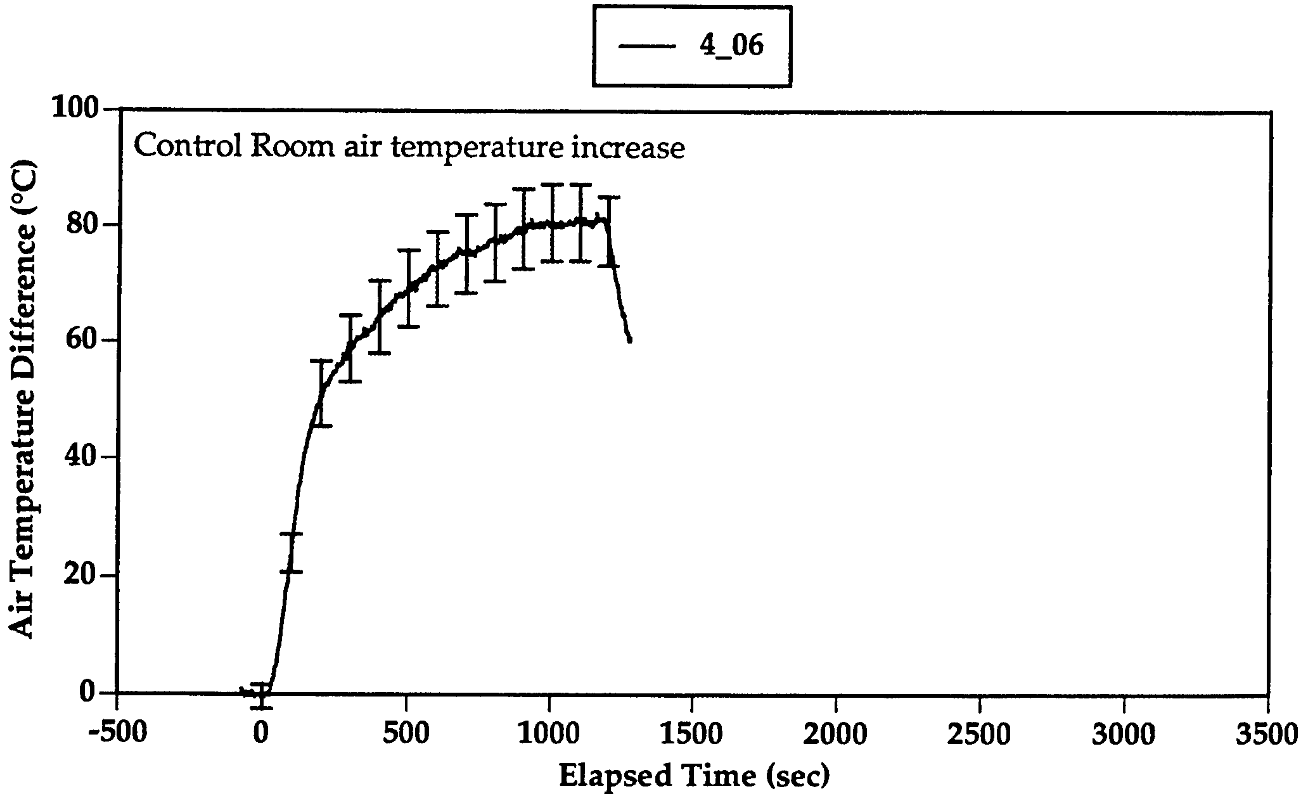


Figure B5. Temperature increase in Control Room and Laundry Room for Test 4_05. Error bars are one standard deviation.



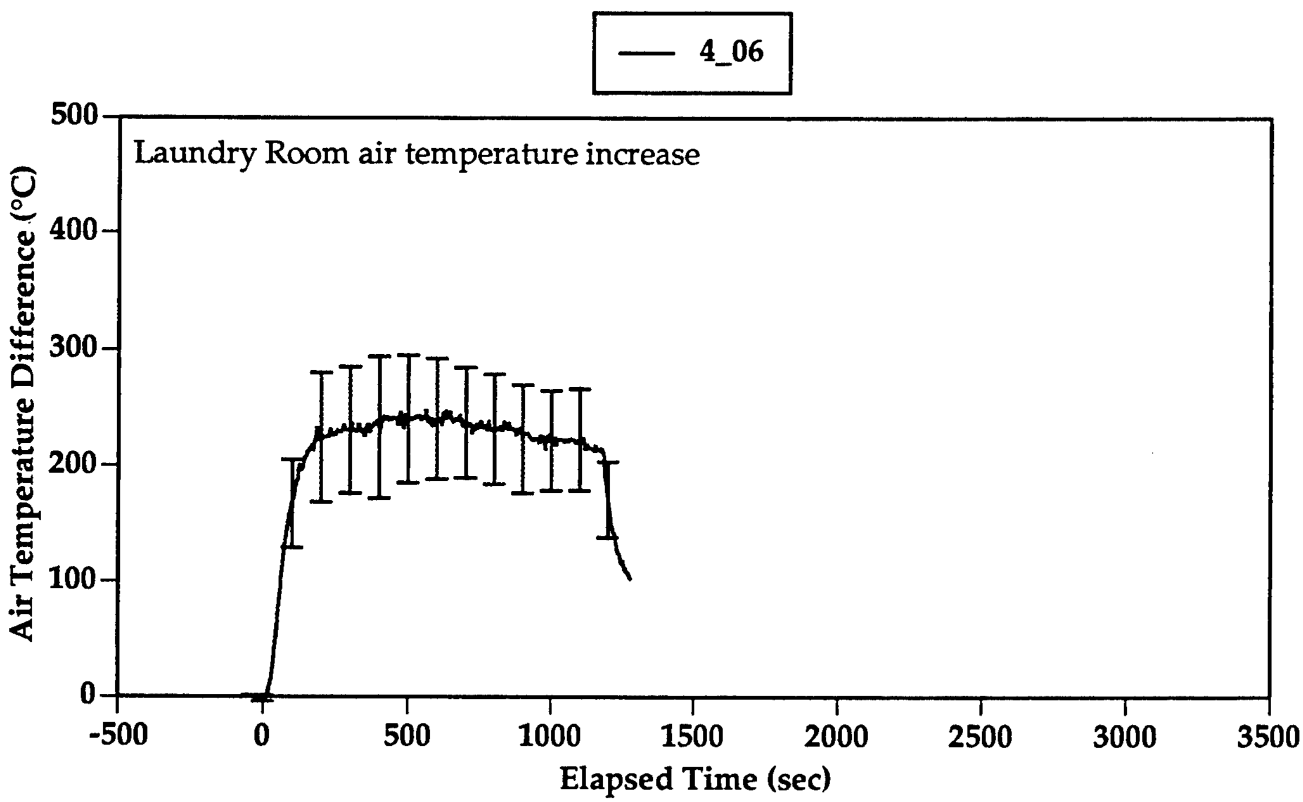
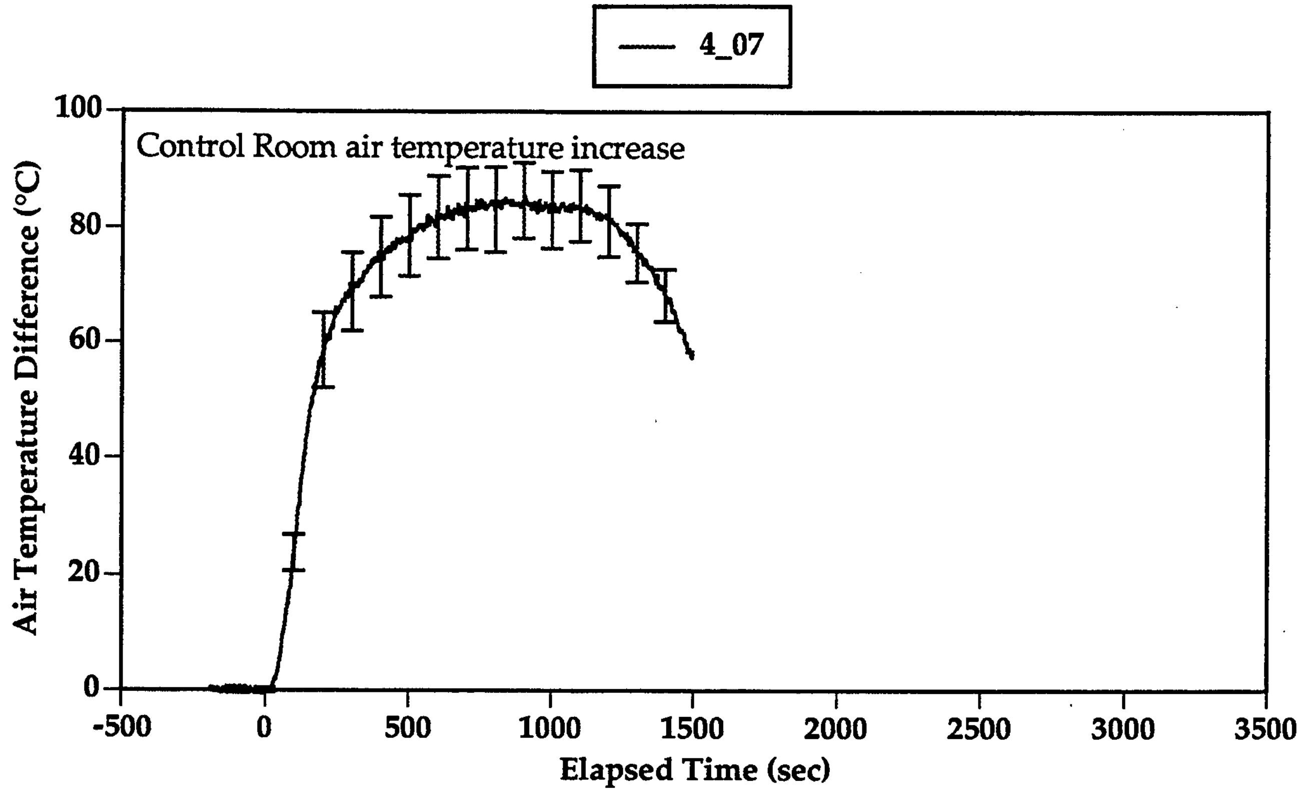


Figure B6. Temperature increase in Control Room and Laundry Room for Test 4_06. Error bars are one standard deviation.



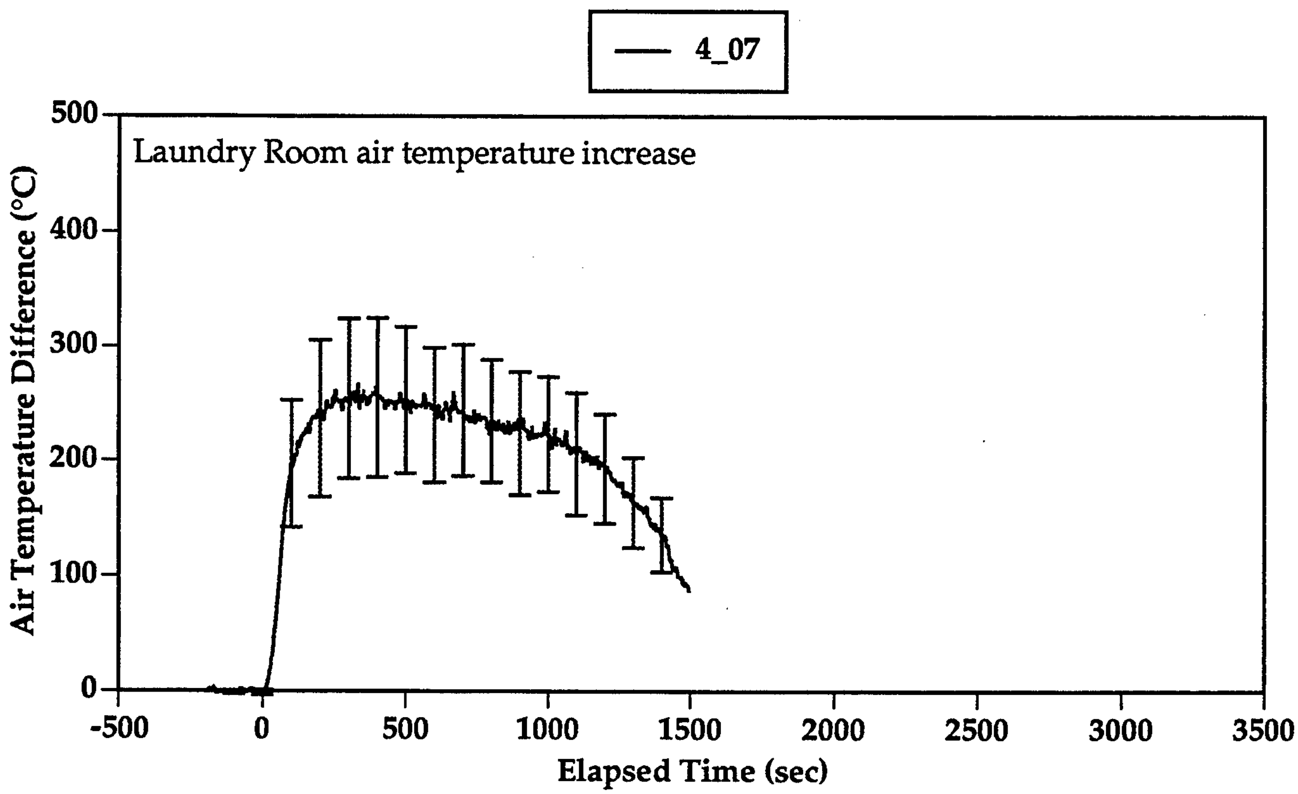
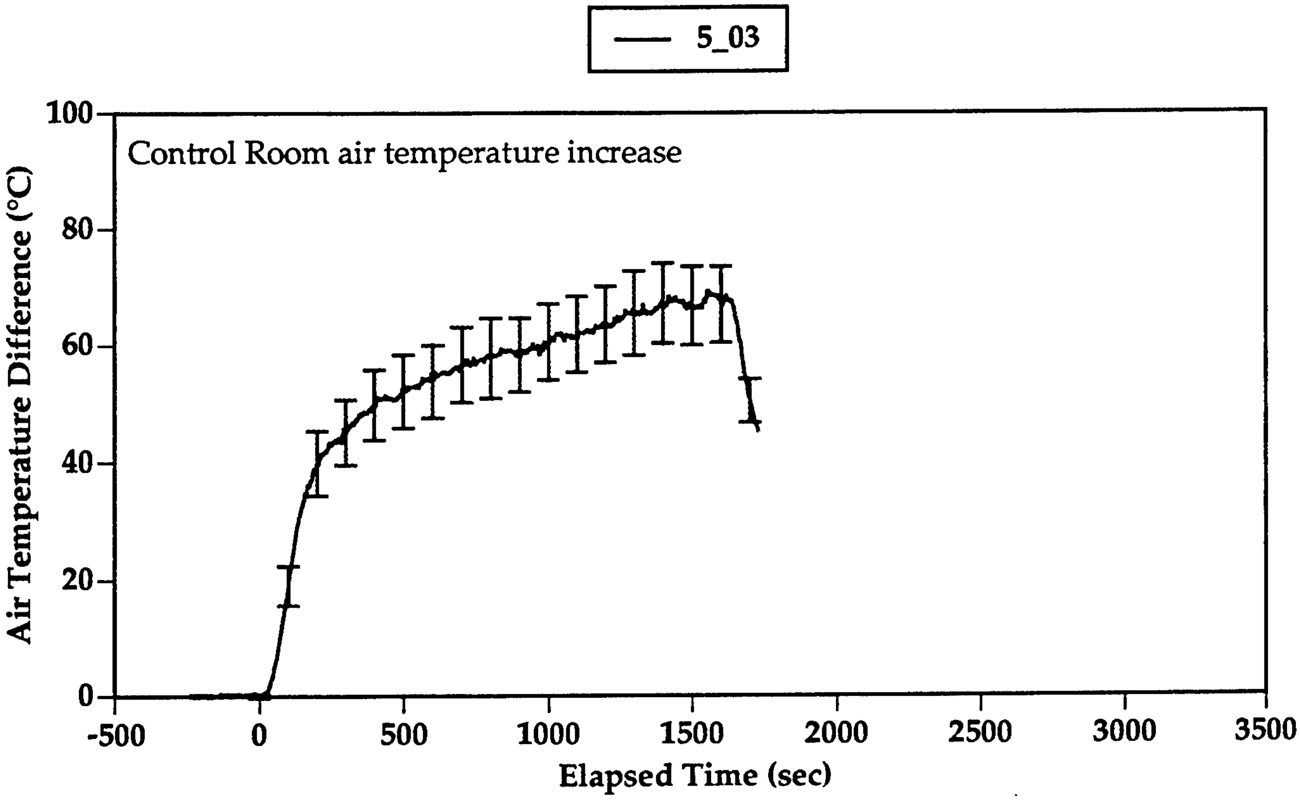


Figure B7. Temperature increase in Control Room and Laundry Room for Test 4_07. Error bars are one standard deviation.



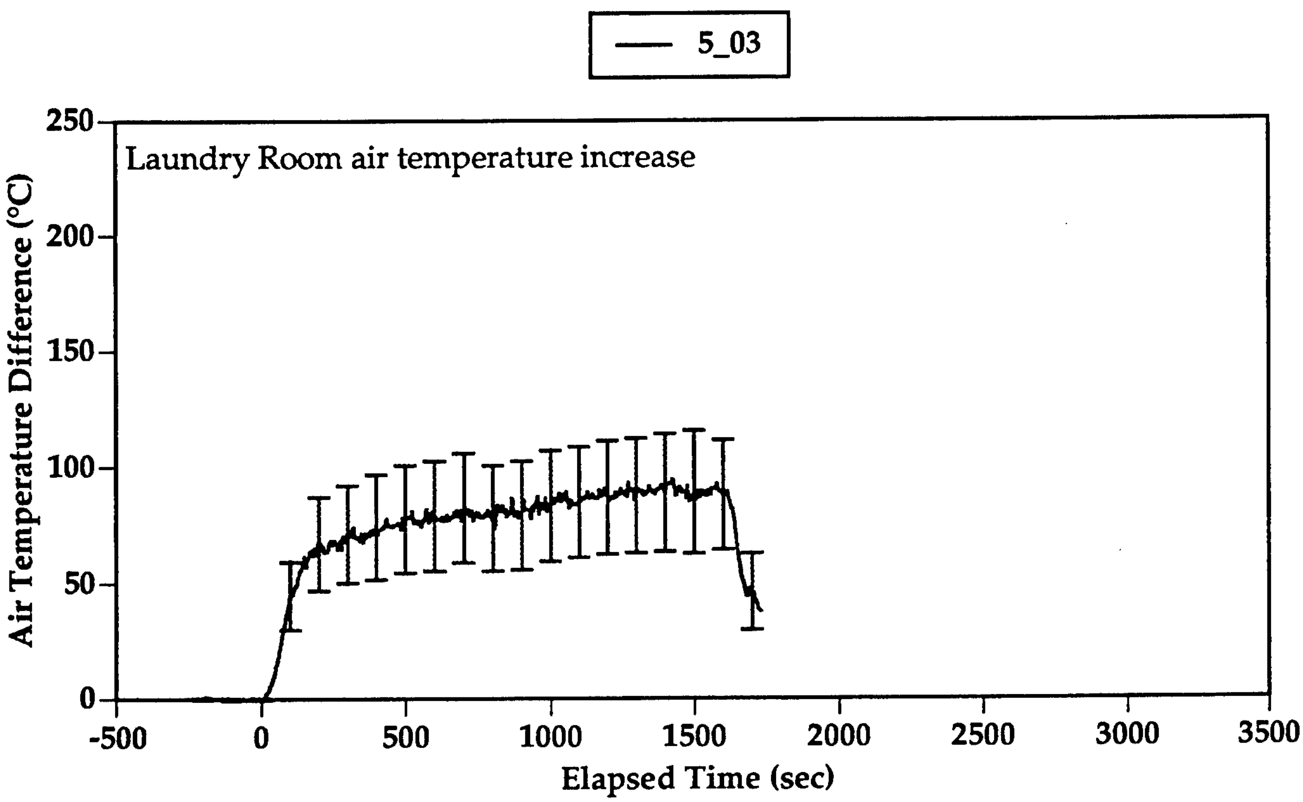


Figure B8. Temperature increase in Control Room and Laundry Room for Test 5_03. Error bars are one standard deviation.

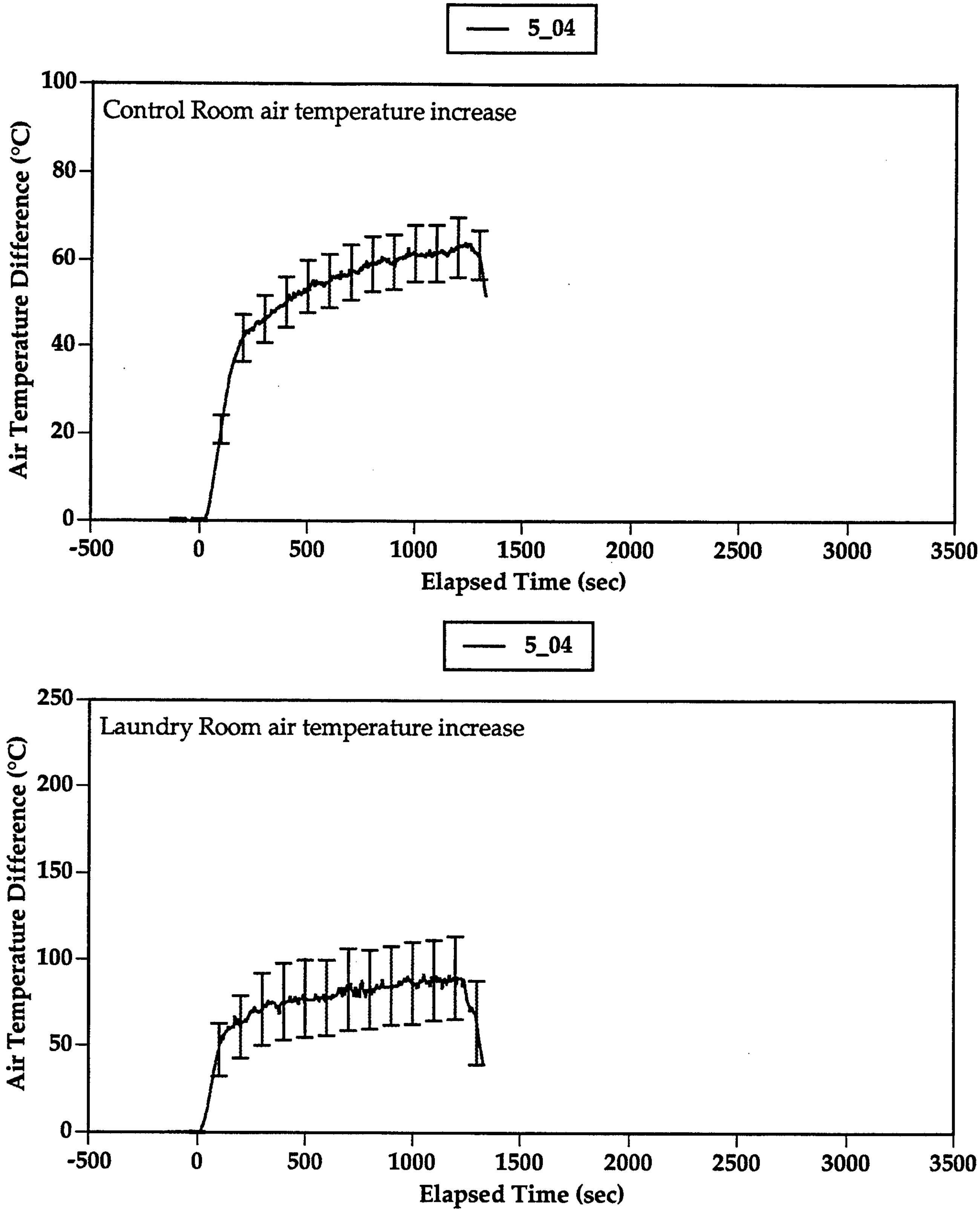
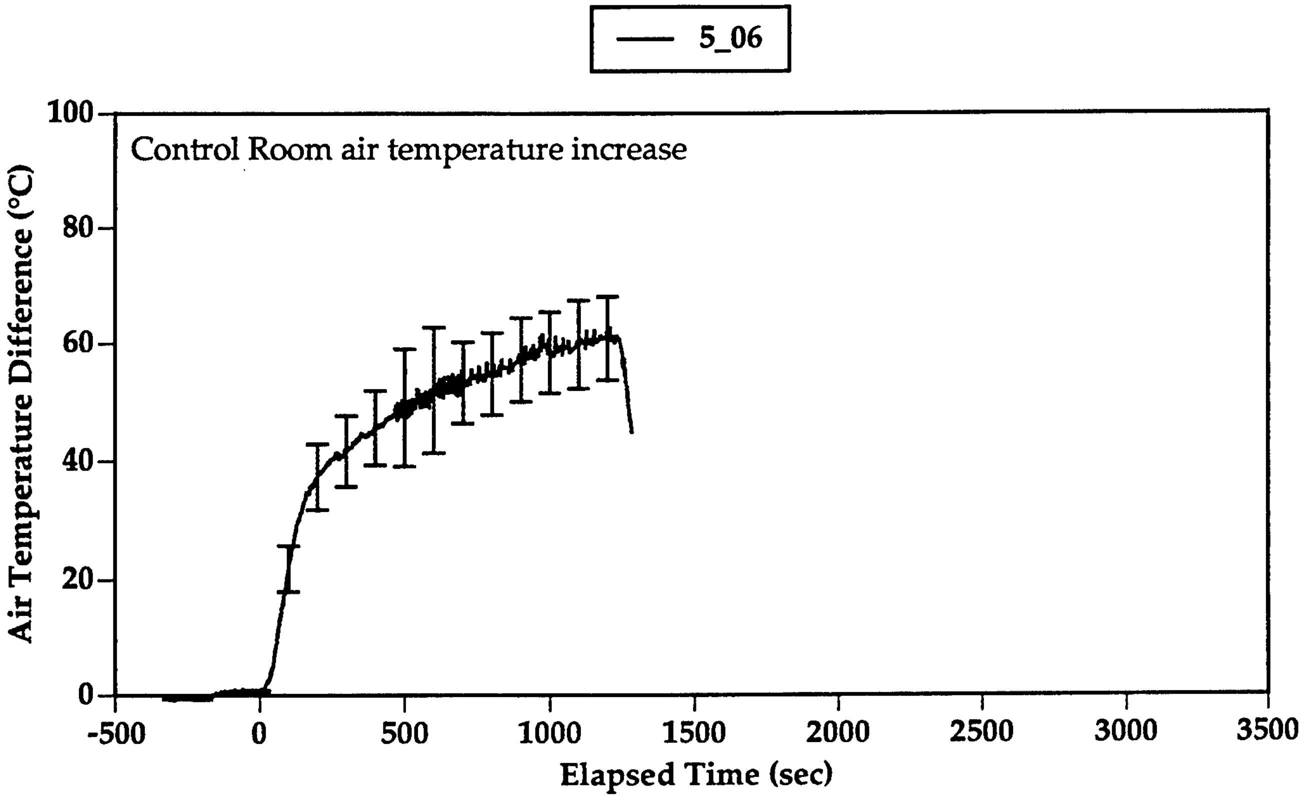


Figure B9. Temperature increase in Control Room and Laundry Room for Test 5_04. Error bars are one standard deviation.



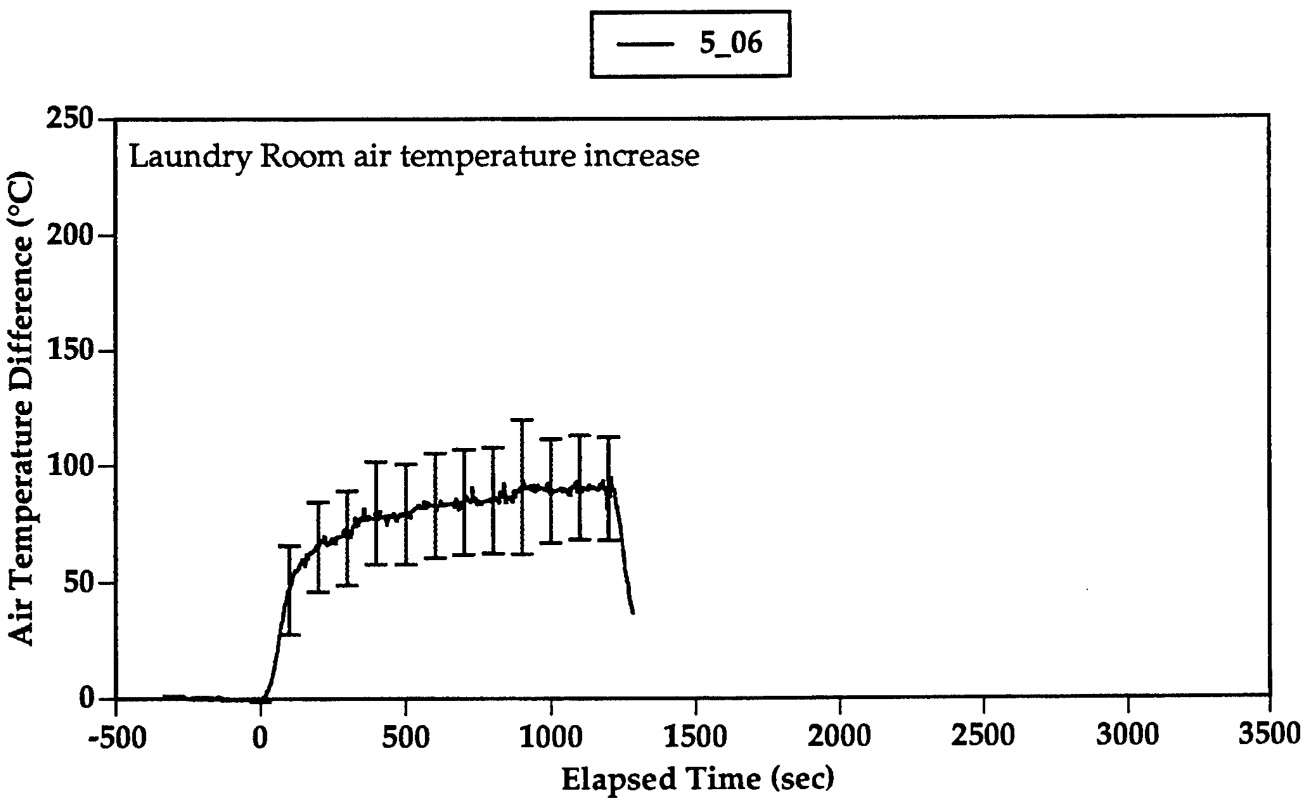
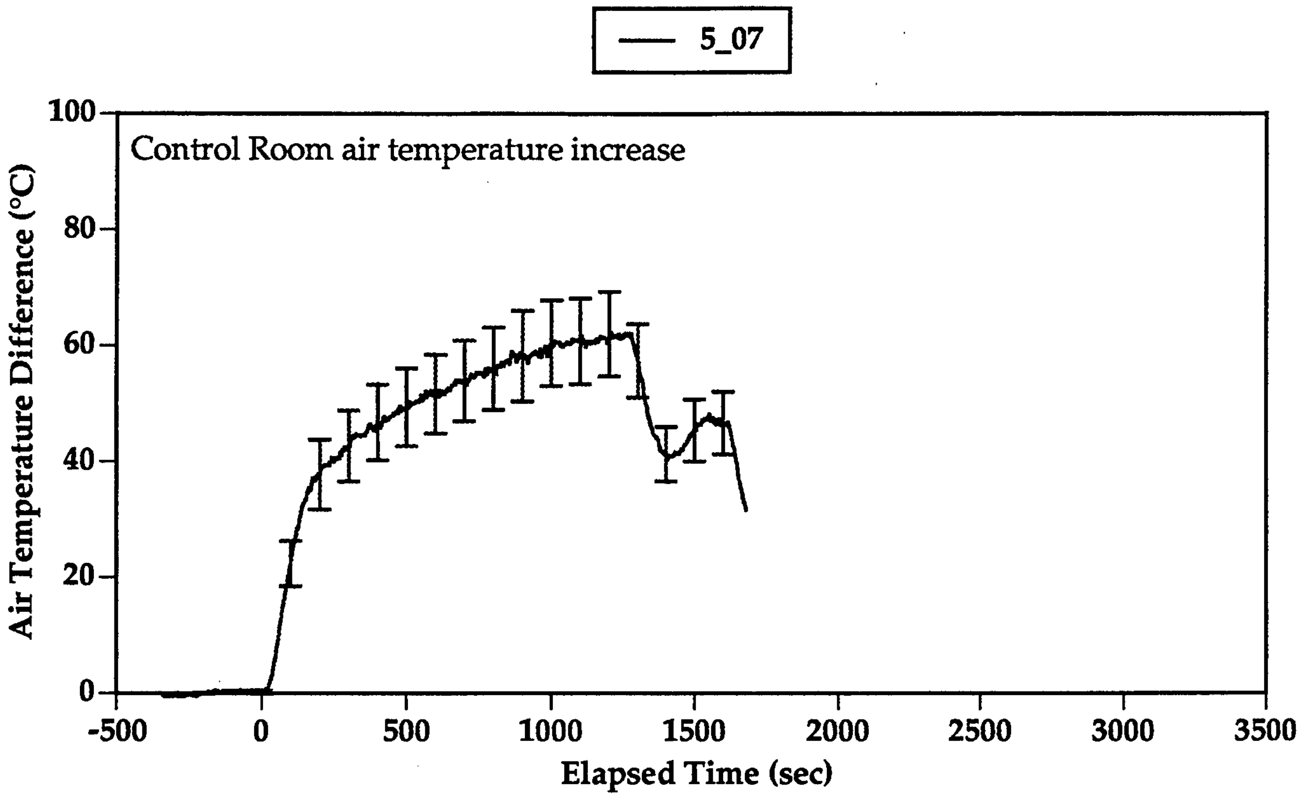


Figure B10. Temperature increase in Control Room and Laundry Room for Test 5_06. Error bars are one standard deviation.



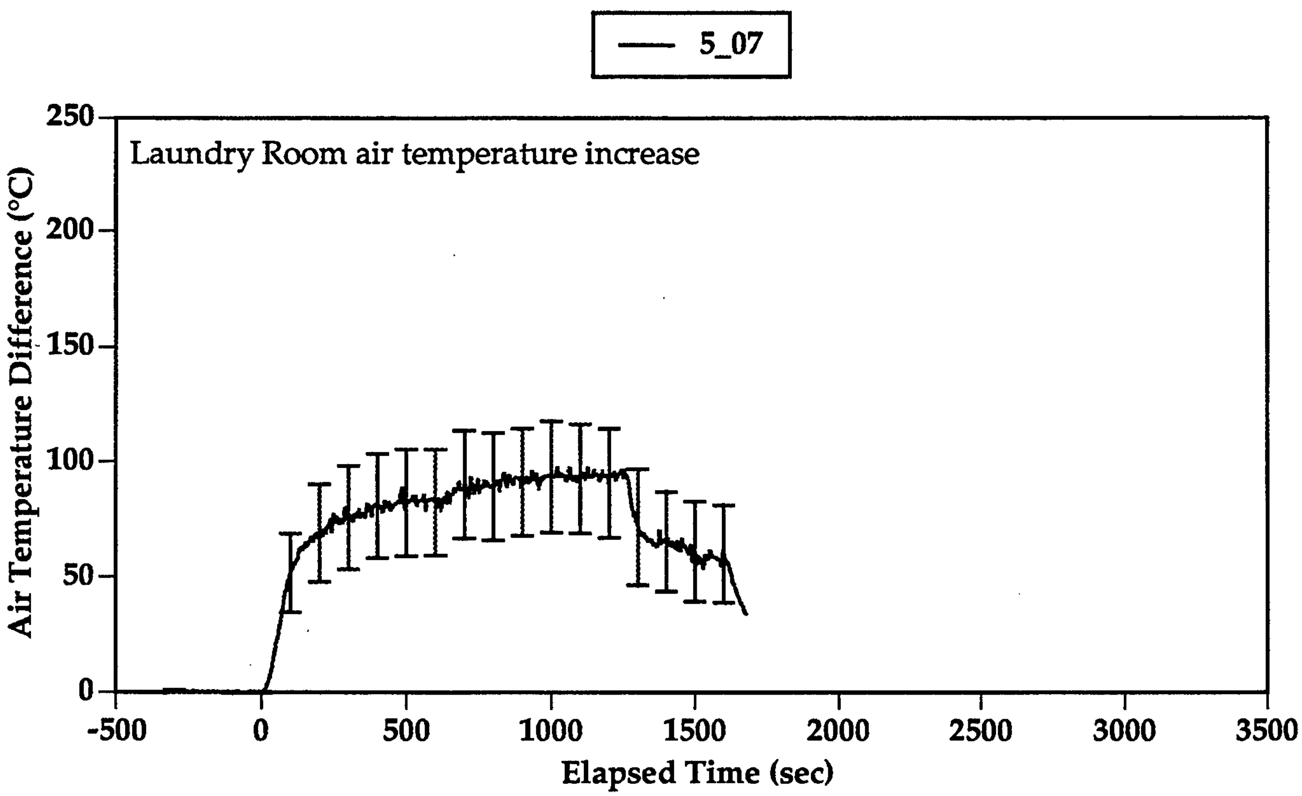
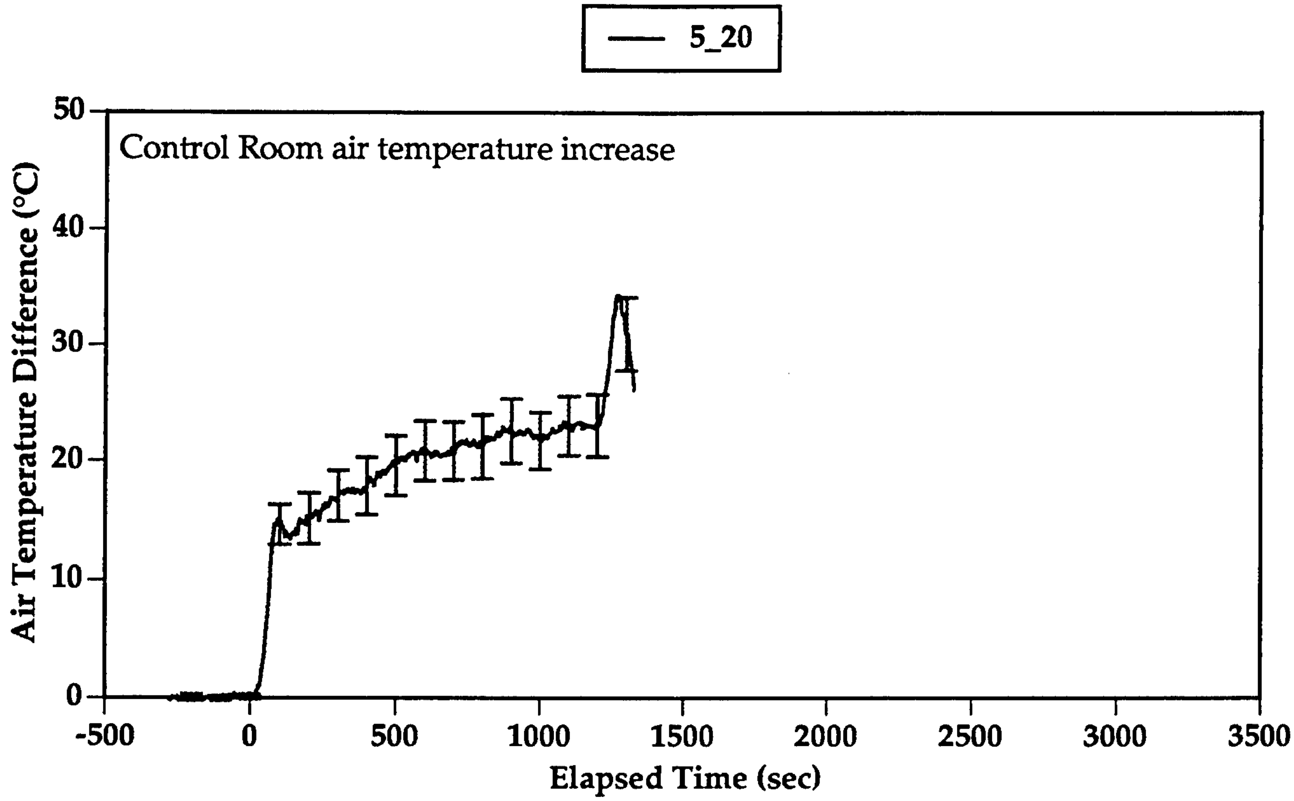


Figure B11. Temperature increase in Control Room and Laundry Room for Test 5_07. Error bars are one standard deviation.



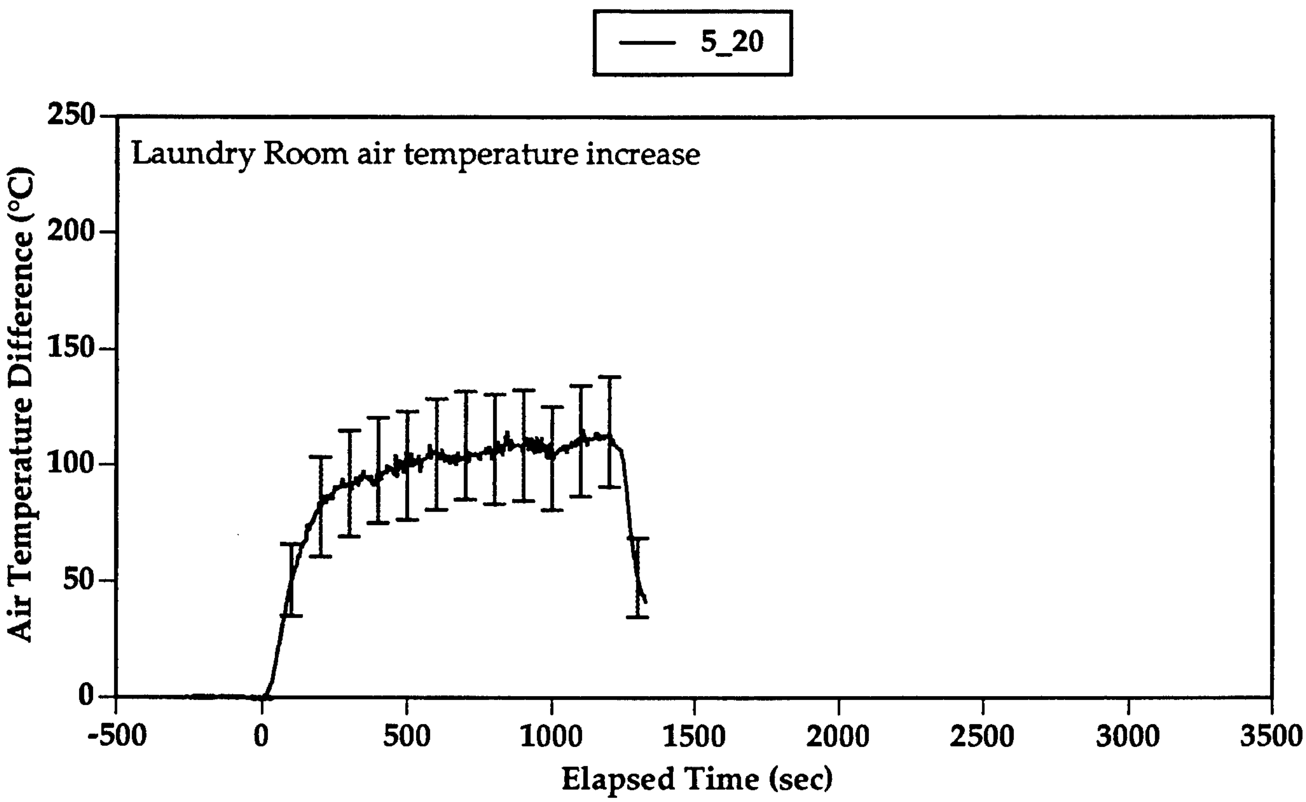


Figure B12. Temperature increase in Control Room and Laundry Room for Test 5_20. Error bars are one standard deviation.

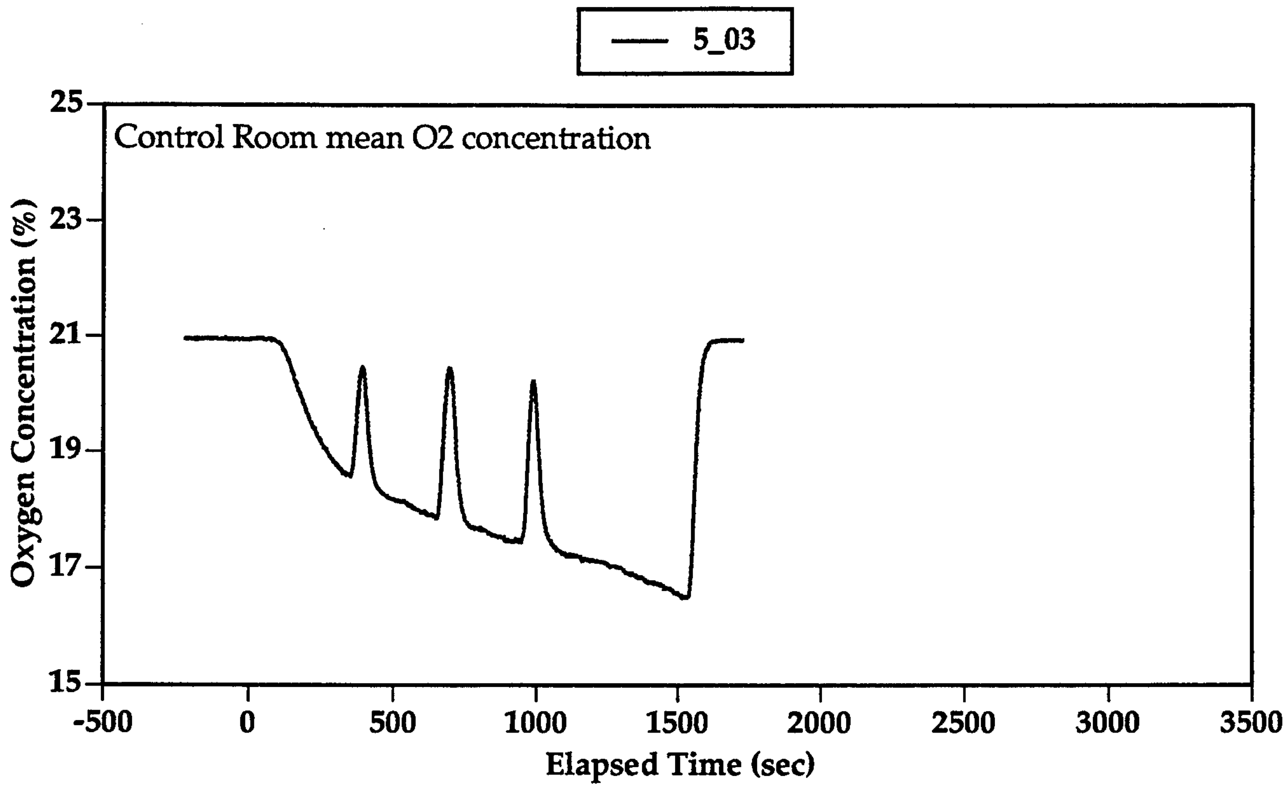
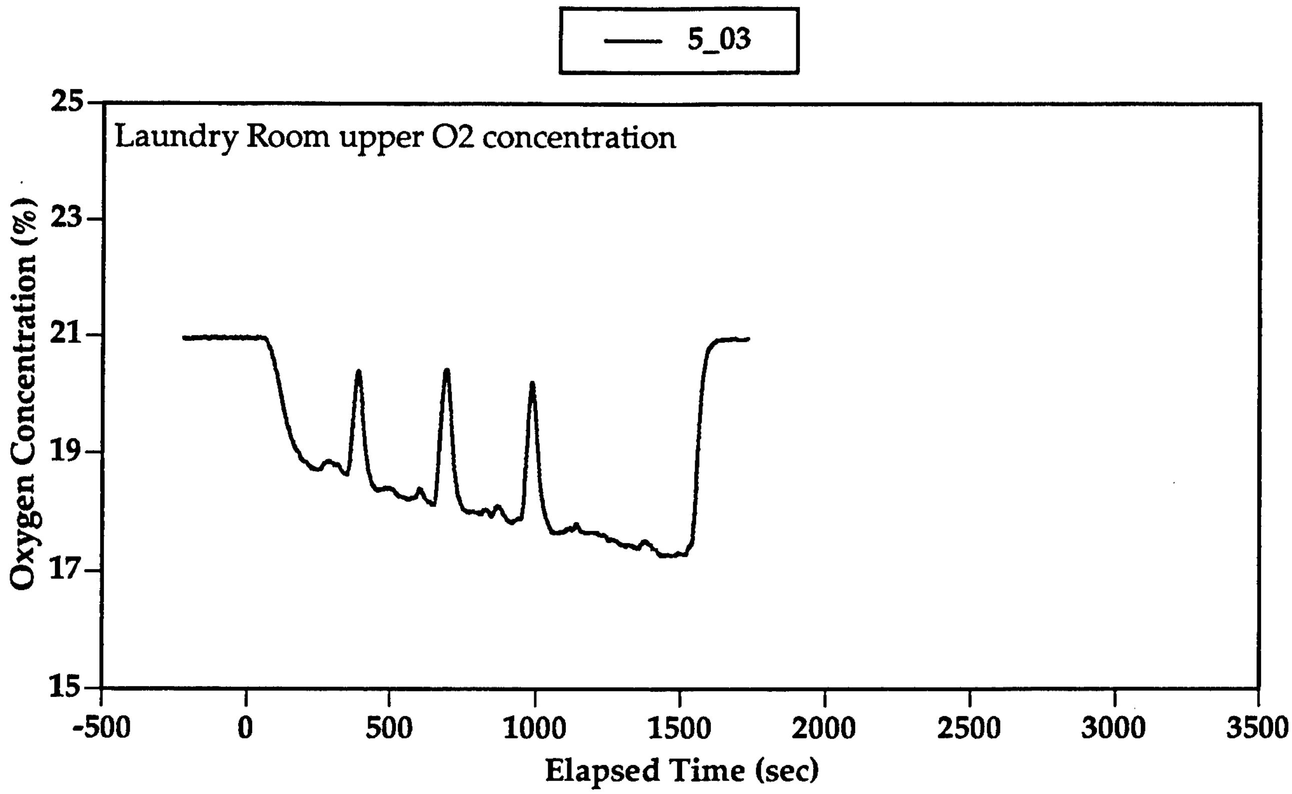


Figure B13. Mean oxygen concentration in Control Room for Test 5_03. Spikes in the data occurred when the instrument was purged with air.



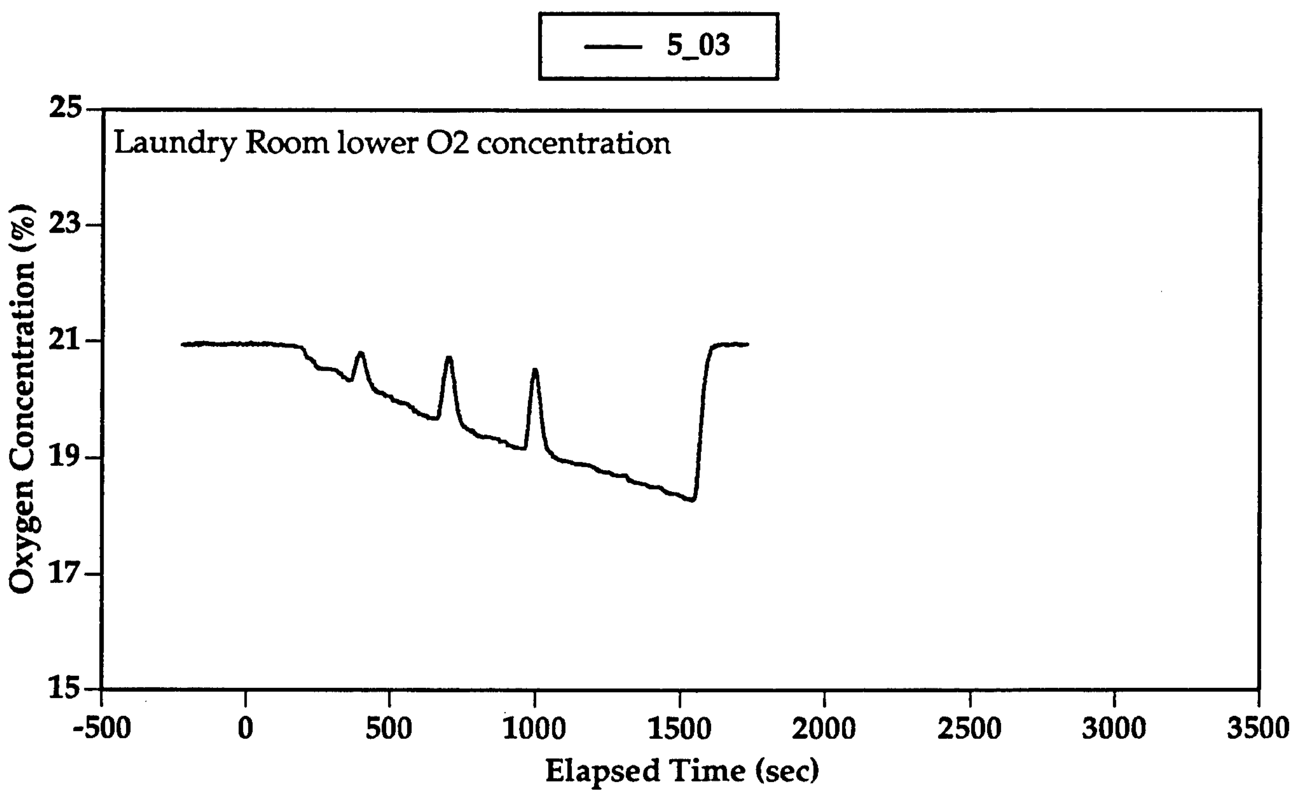


Figure B14. Upper and lower oxygen concentrations in Laundry Room for Test 5_03. Spikes in the data occurred when the instrument was purged with air.

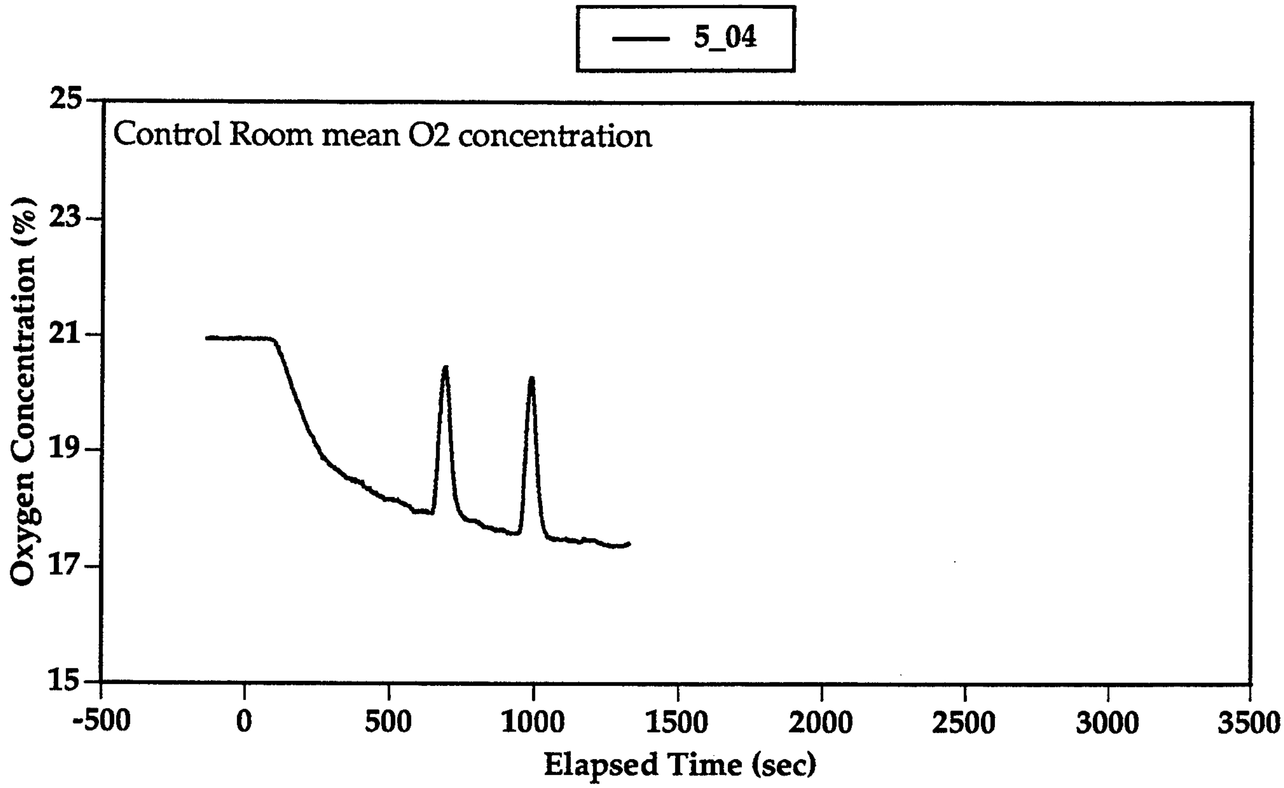
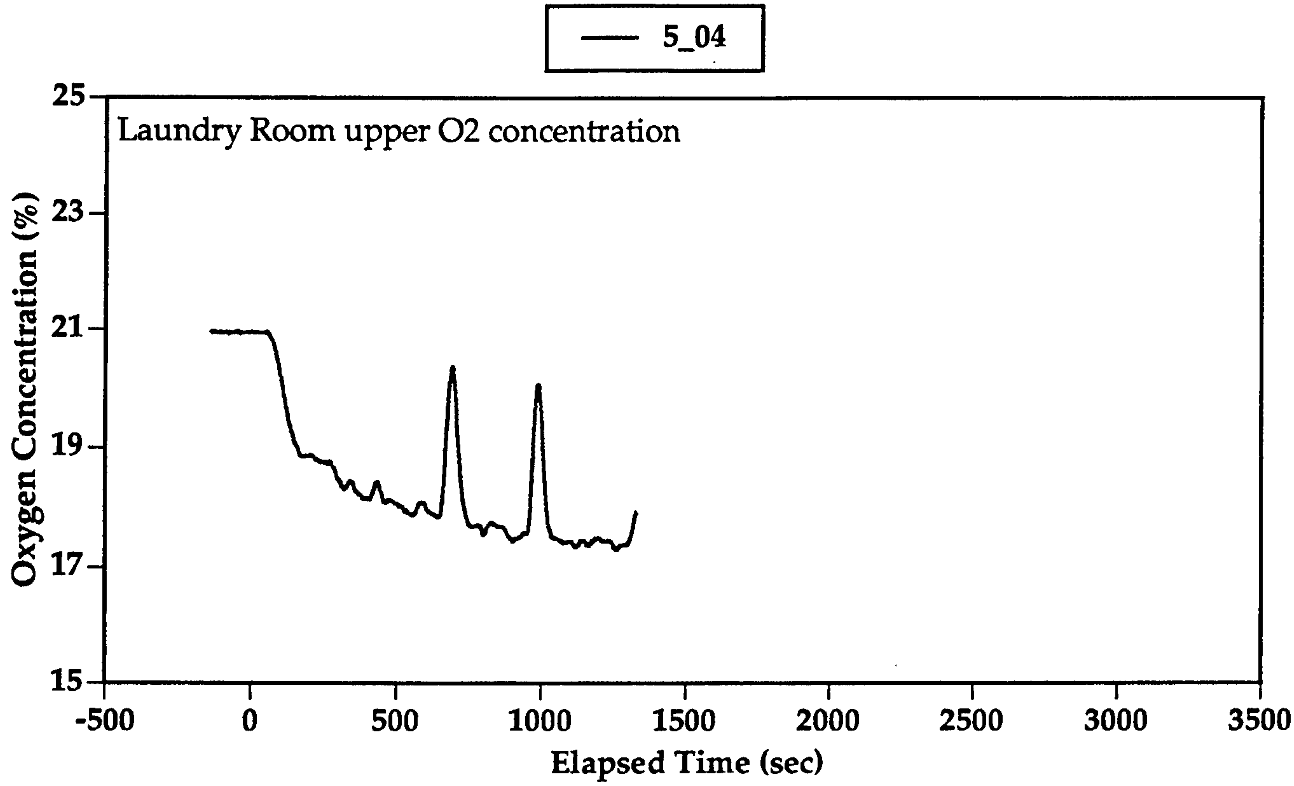


Figure B15. Mean oxygen concentration in Control Room for Test 5_04. Spikes in the data occurred when the instrument was purged with air.



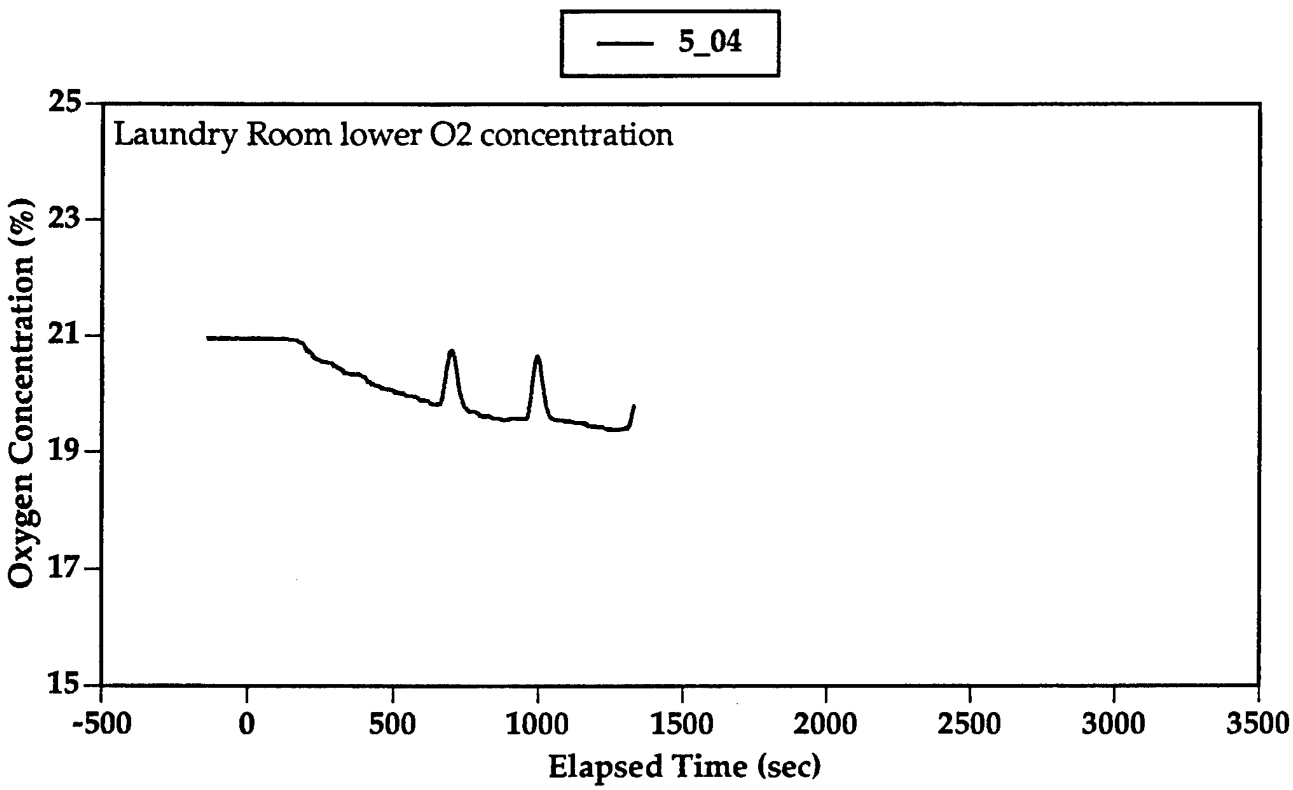


Figure B16. Upper and lower oxygen concentrations in Laundry Room for Test 5_04. Spikes in the data occurred when the instrument was purged with air.

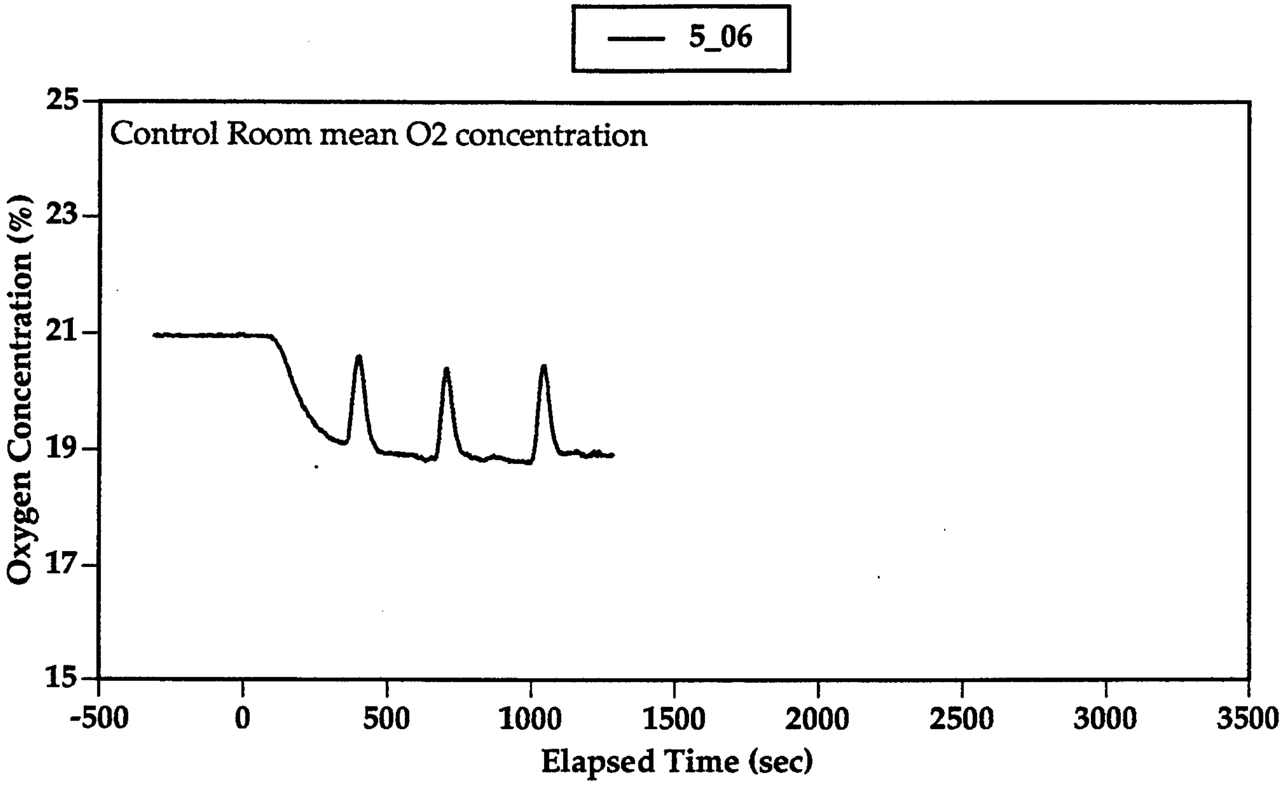
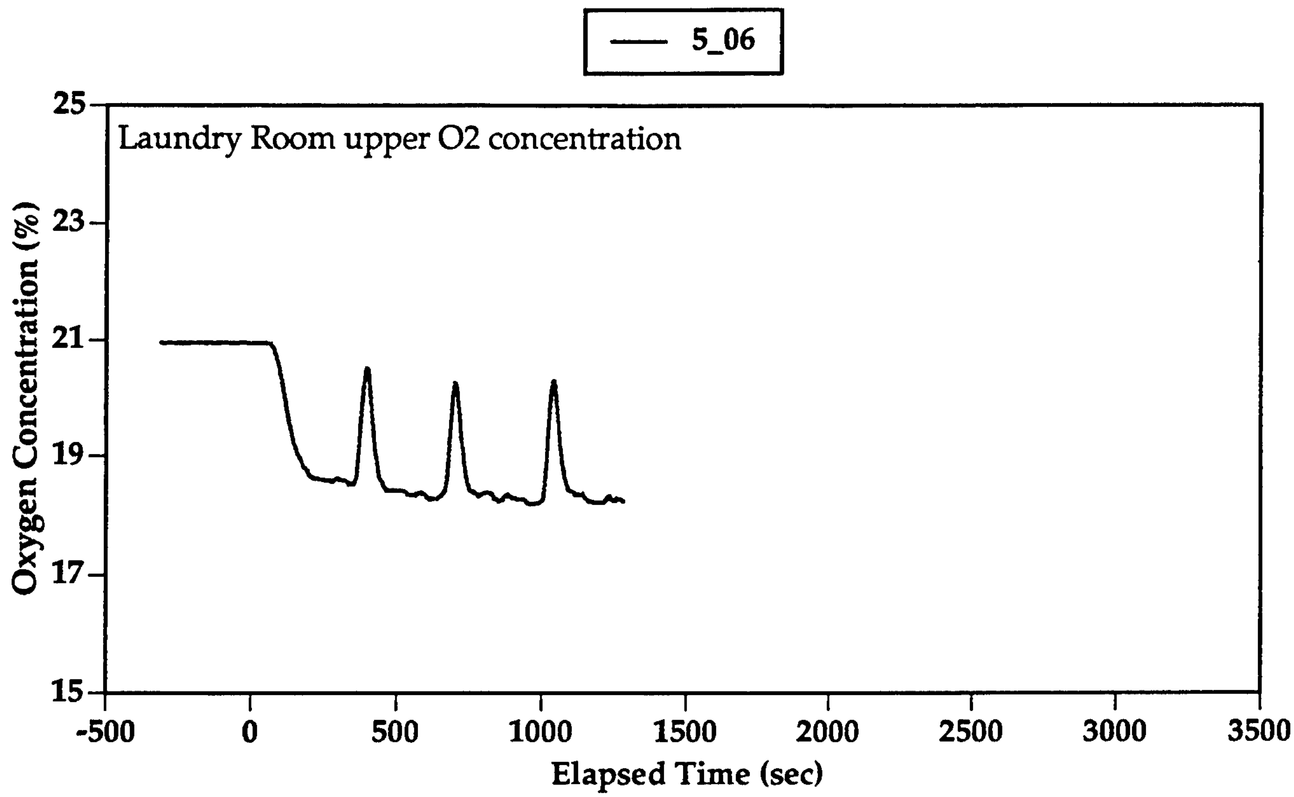


Figure B17. Mean oxygen concentration in Control Room for Test 5_06. Spikes in the data occurred when the instrument was purged with air.



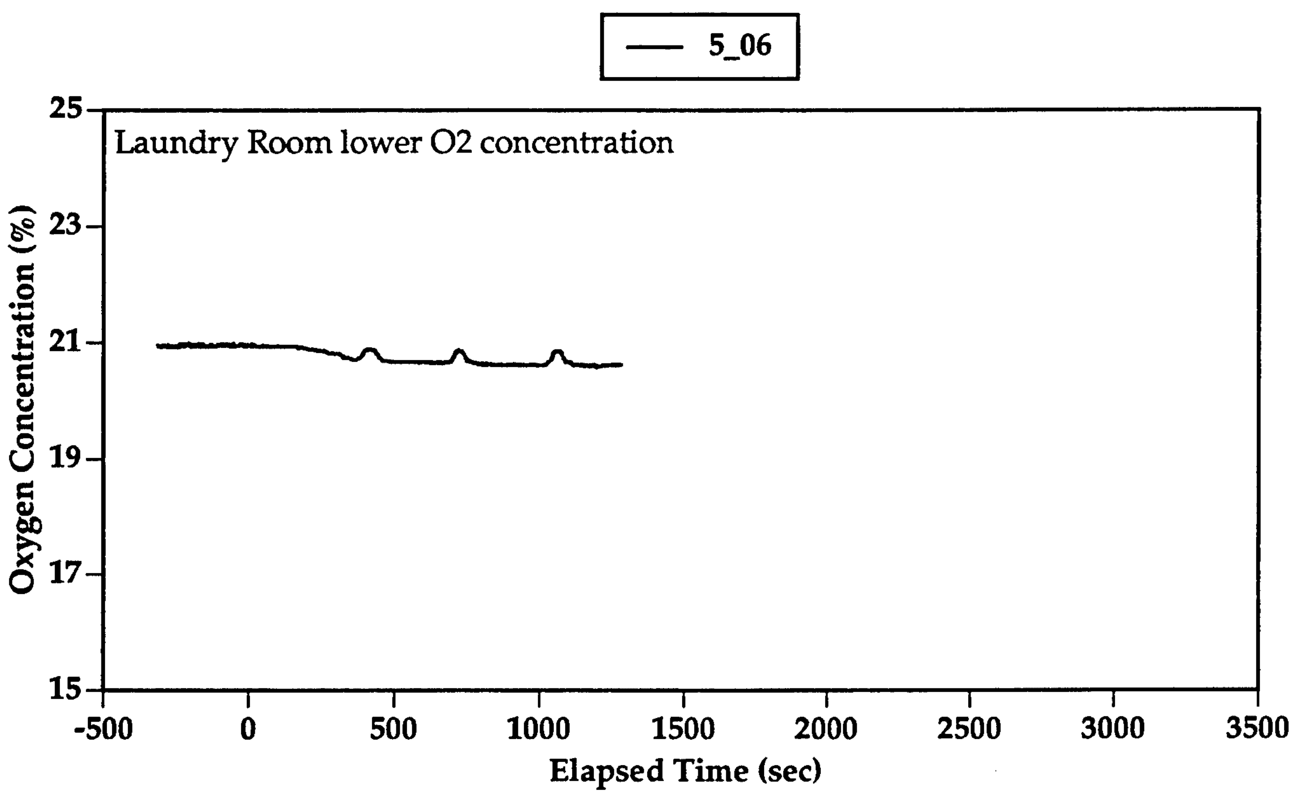


Figure B18. Upper and lower oxygen concentrations in Laundry Room for Test 5_06. Spikes in the data occurred when the instrument was purged with air.

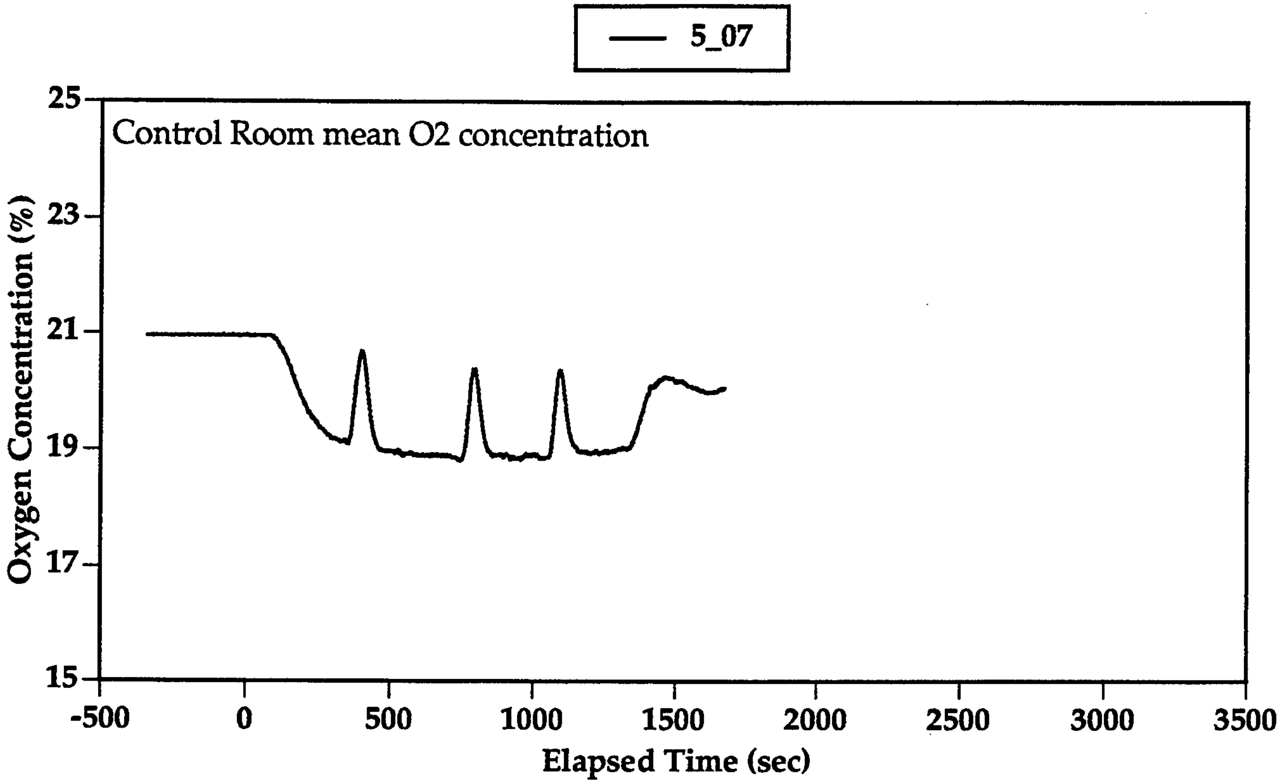


Figure B19. Mean oxygen concentration in Control Room for Test 5_07. Spikes in the data occurred when the instrument was purged with air.

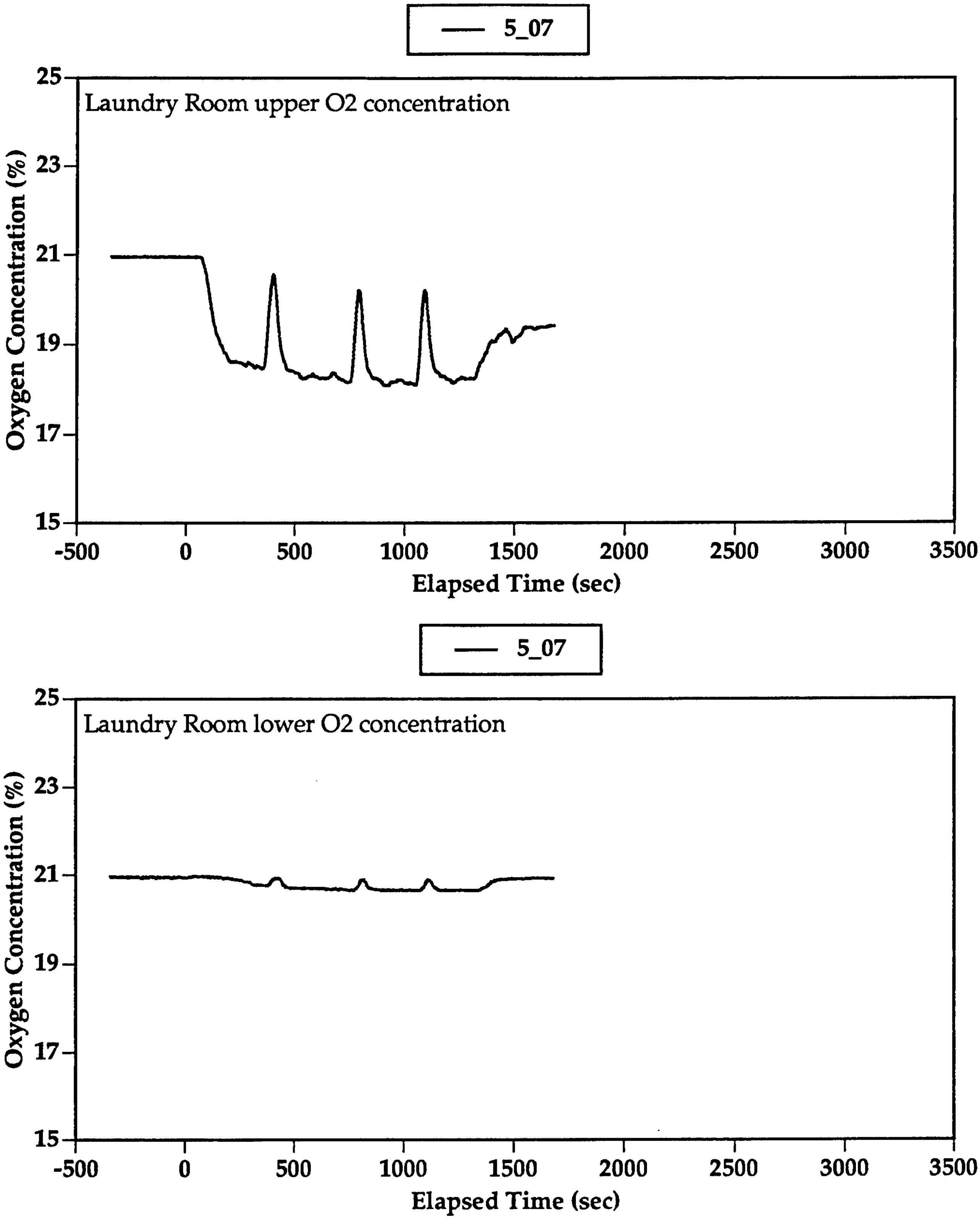


Figure B20. Upper and lower oxygen concentrations in Laundry Room for Test 5_07. Spikes in the data occurred when the instrument was purged with air.

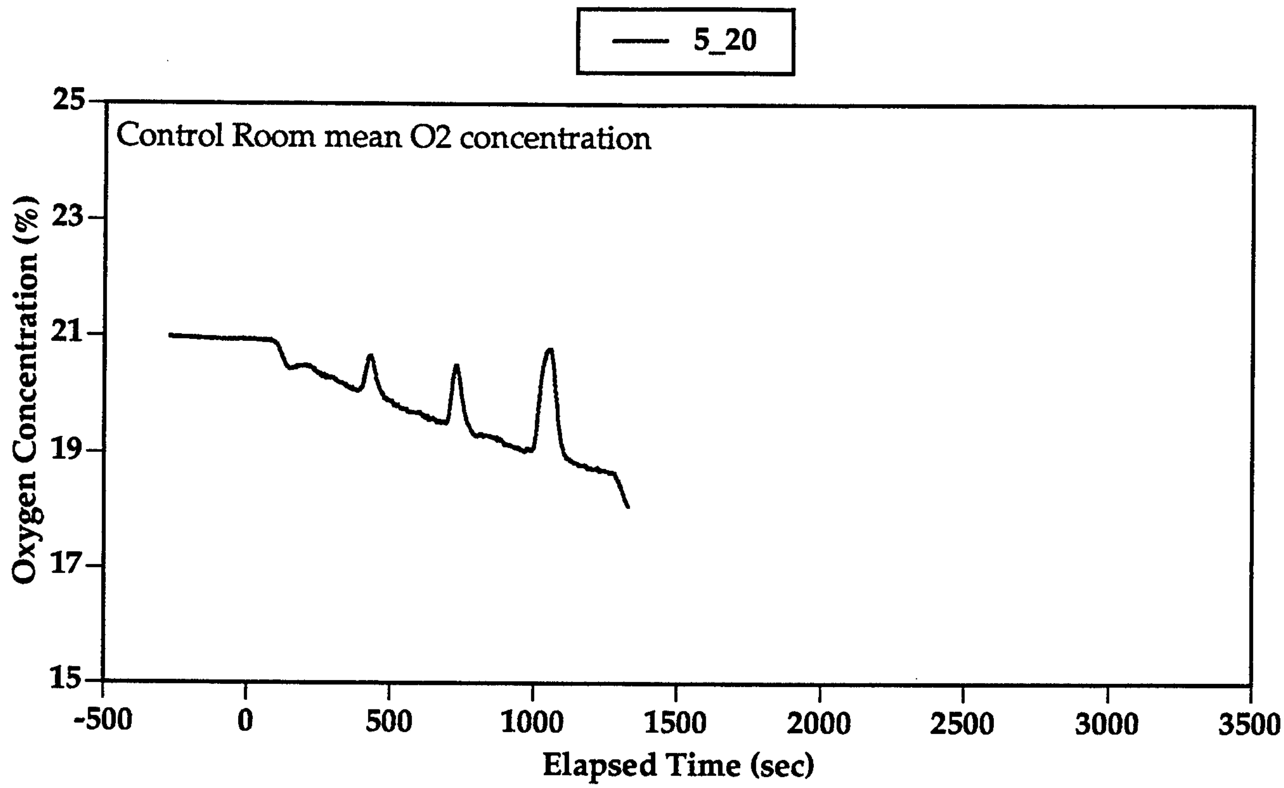
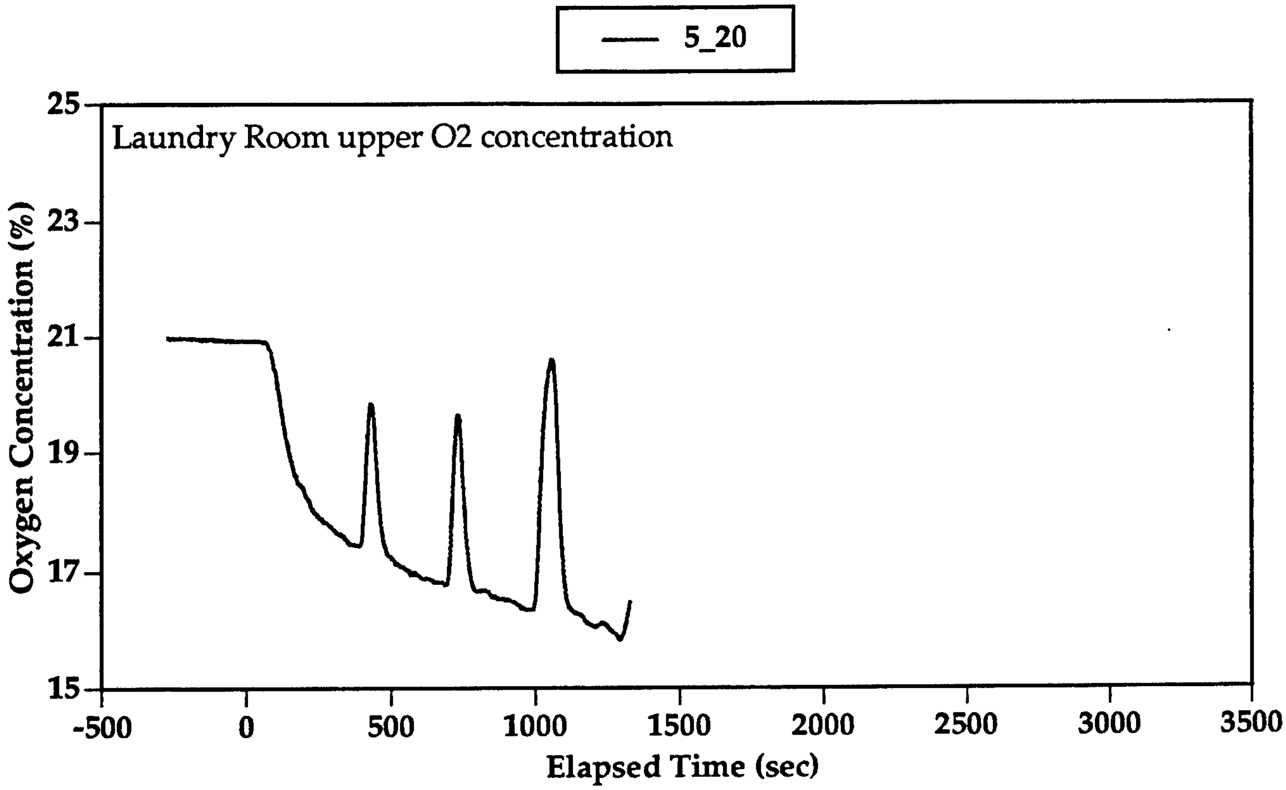


Figure B21. Mean oxygen concentration in Control Room for Test 5_20. Spikes in the data occurred when the instrument was purged with air.



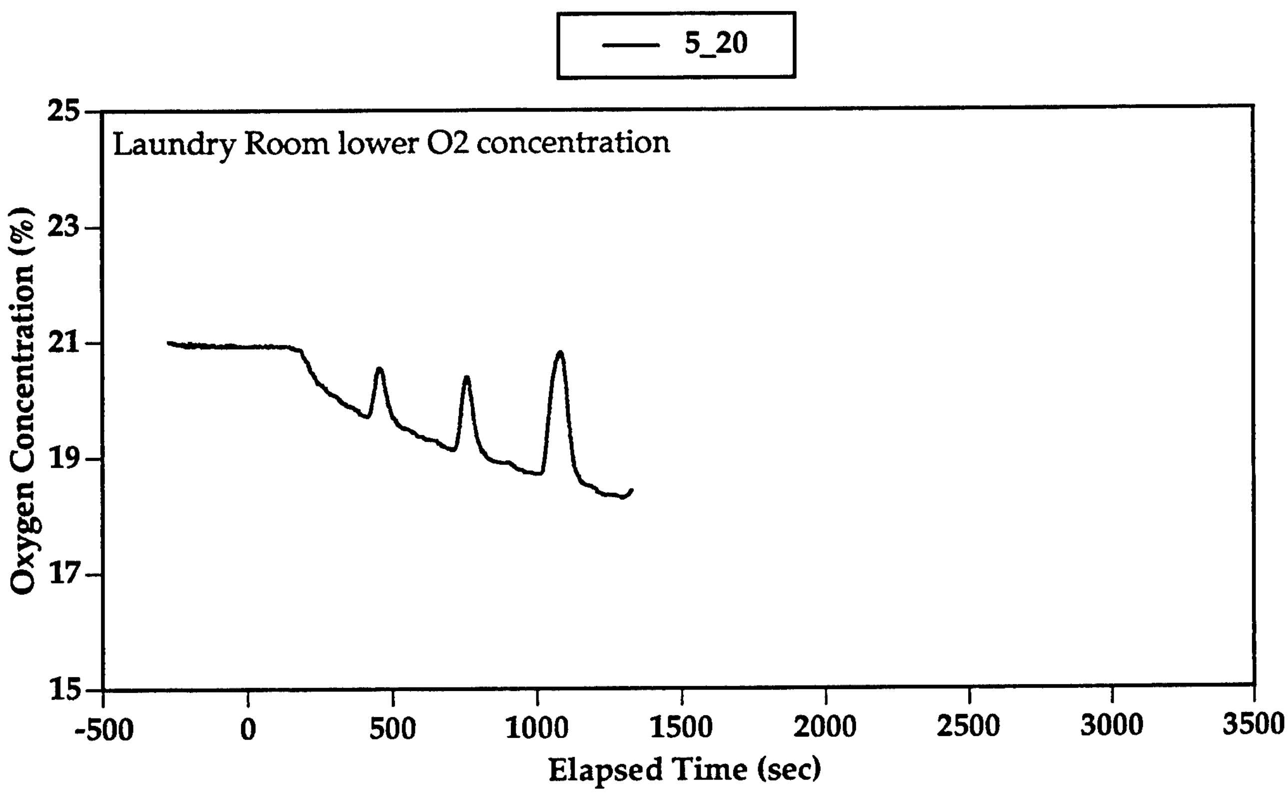


Figure B22. Upper and lower oxygen concentrations in Laundry Room for Test 5_20. Spikes in the data occurred when the instrument was purged with air.

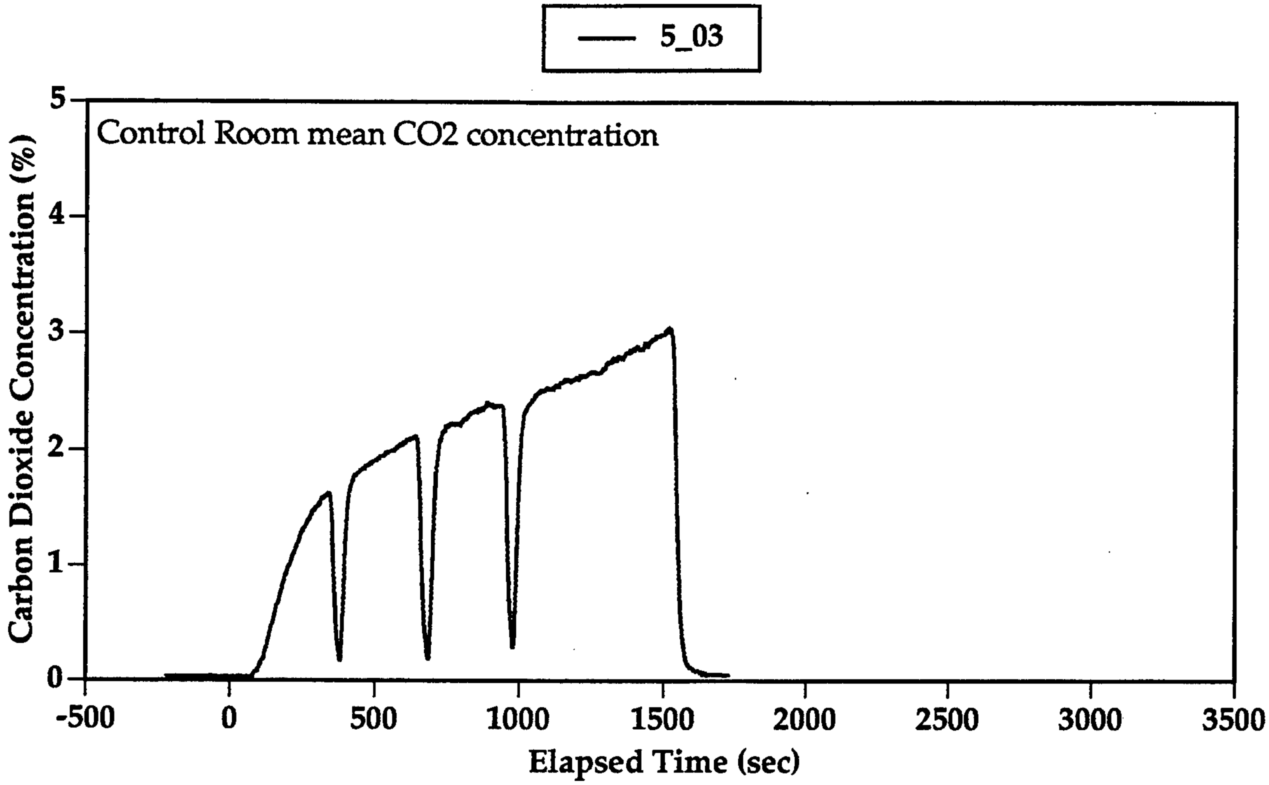
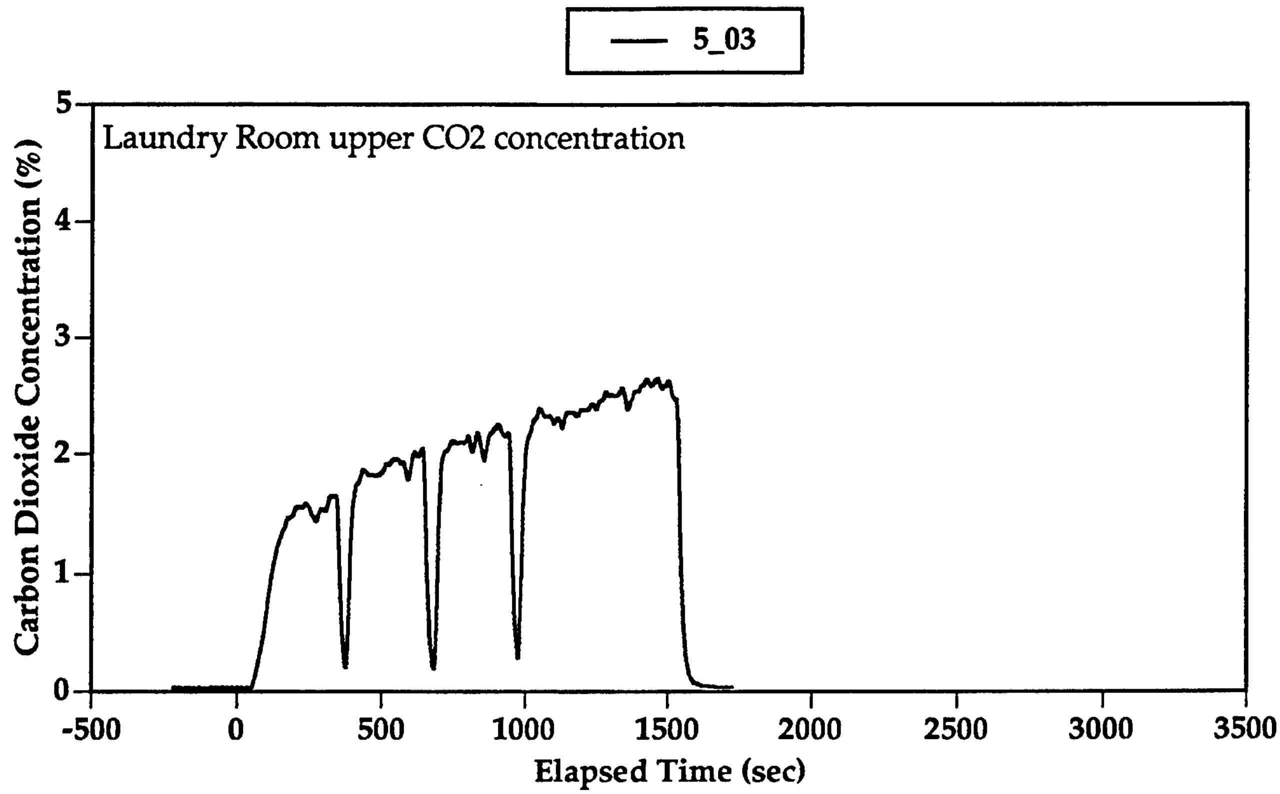


Figure B23. Mean carbon dioxide concentration in Control Room for Test 5_03. Spikes in the data occurred when the instrument was purged with air.



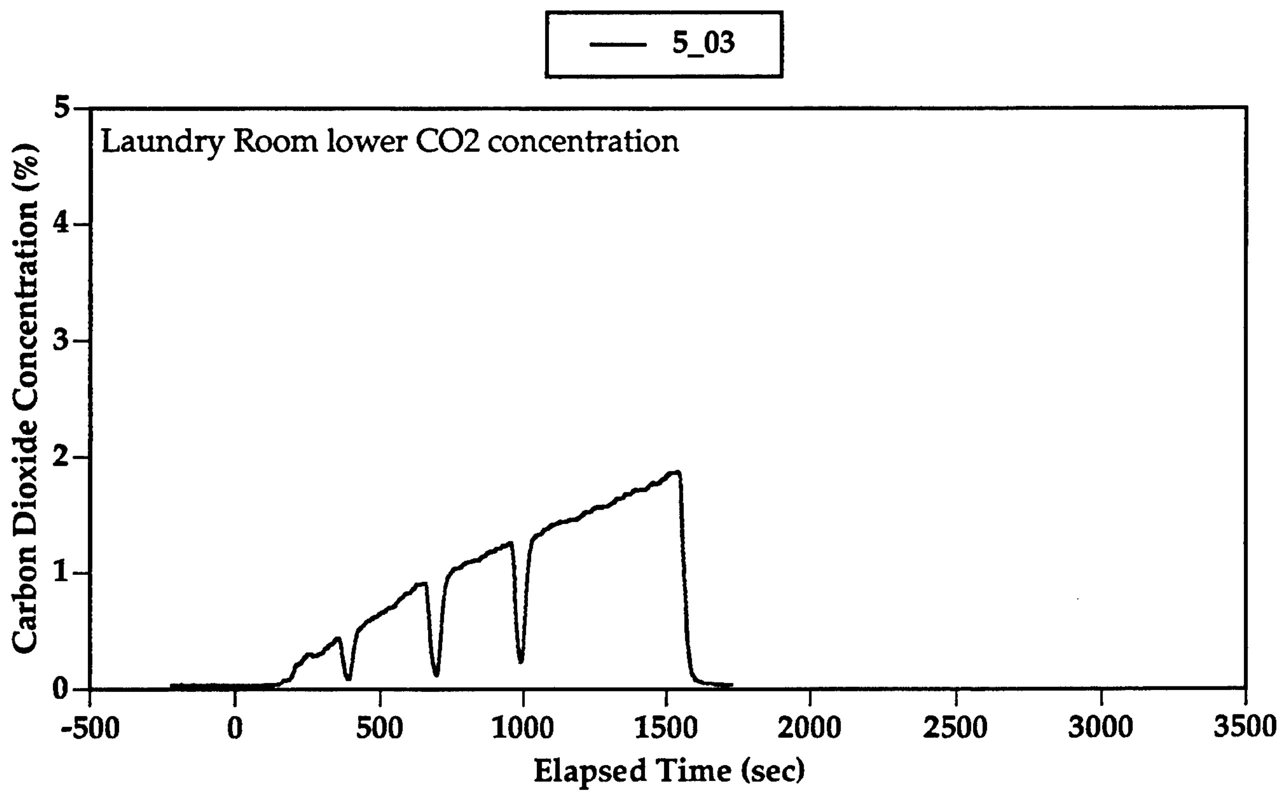


Figure B24. Upper and lower carbon dioxide concentrations in Laundry Room for Test 5_03. Spikes in the data occurred when the instrument was purged with air.

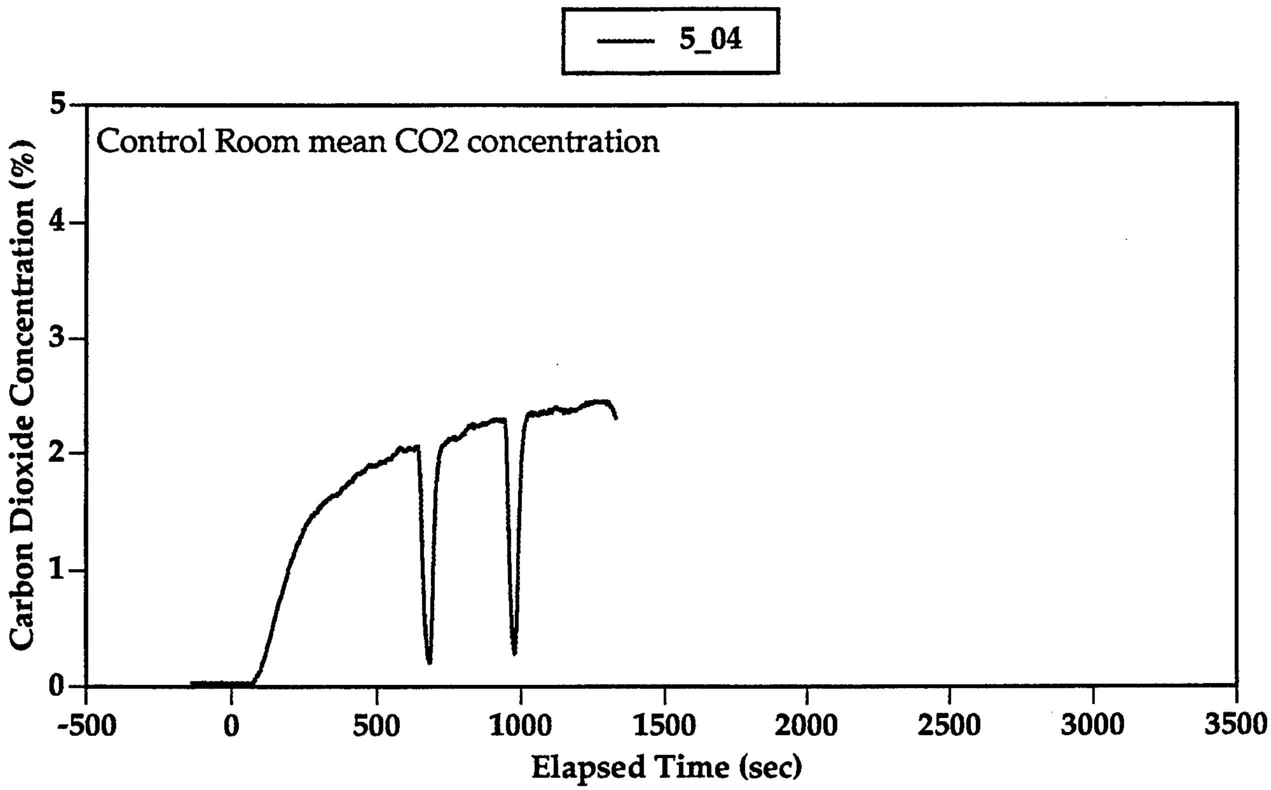
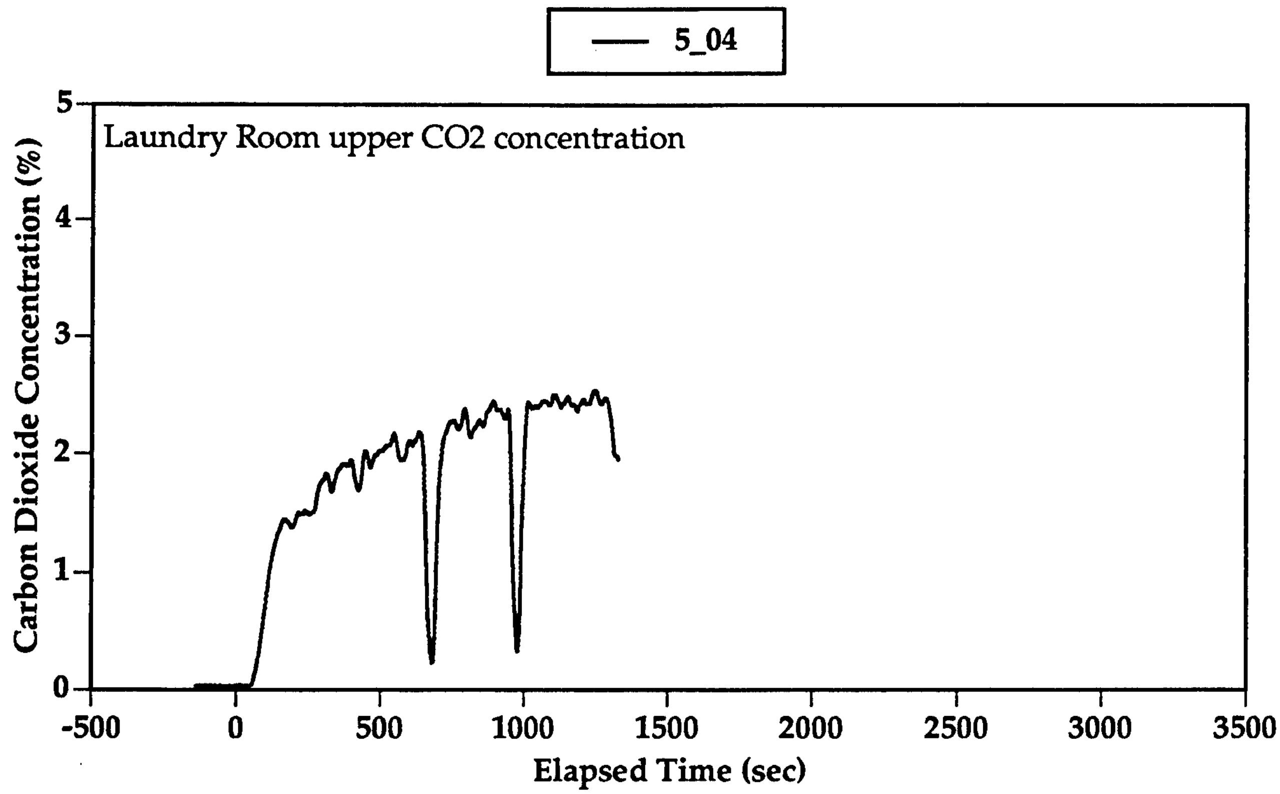


Figure B25. Mean carbon dioxide concentration in Control Room for Test 5_04. Spikes in the data occurred when the instrument was purged with air.



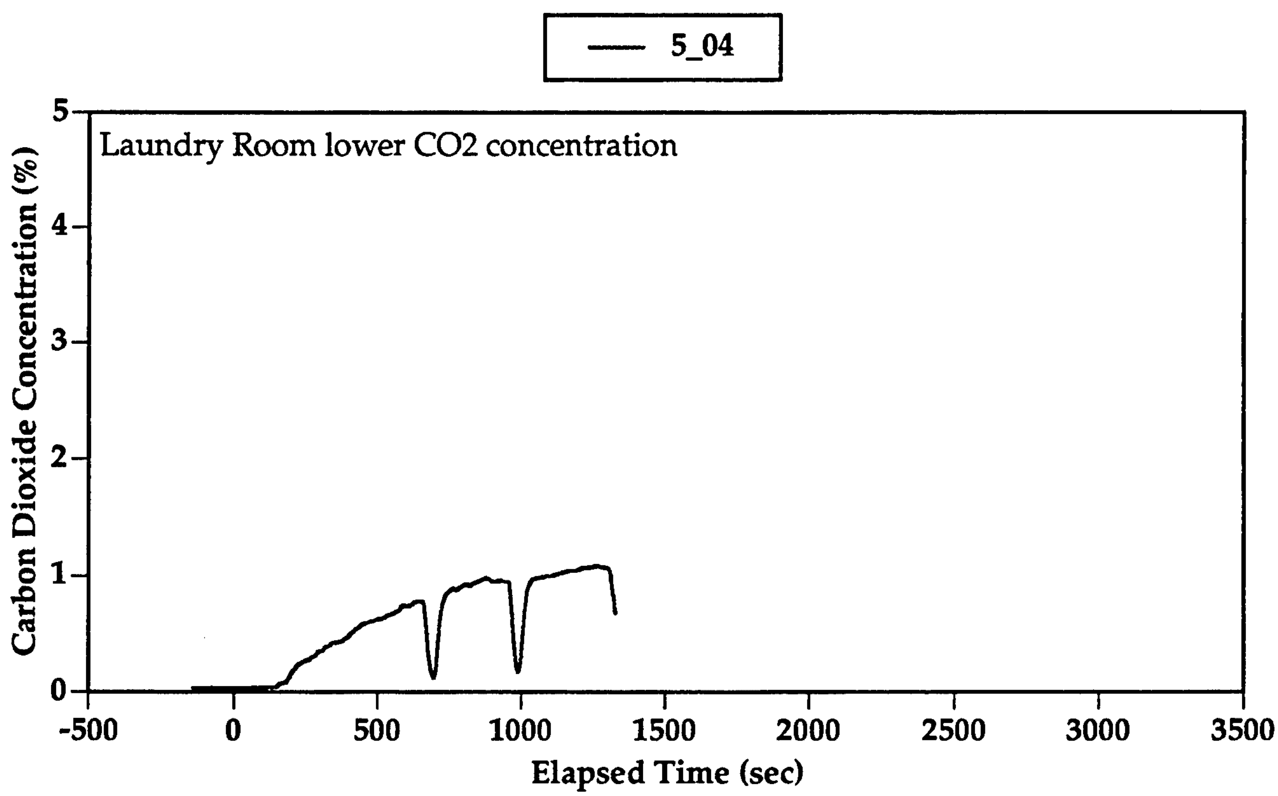


Figure B26. Upper and lower carbon dioxide concentrations in Laundry Room for Test 5_04. Spikes in the data occurred when the instrument was purged with air.

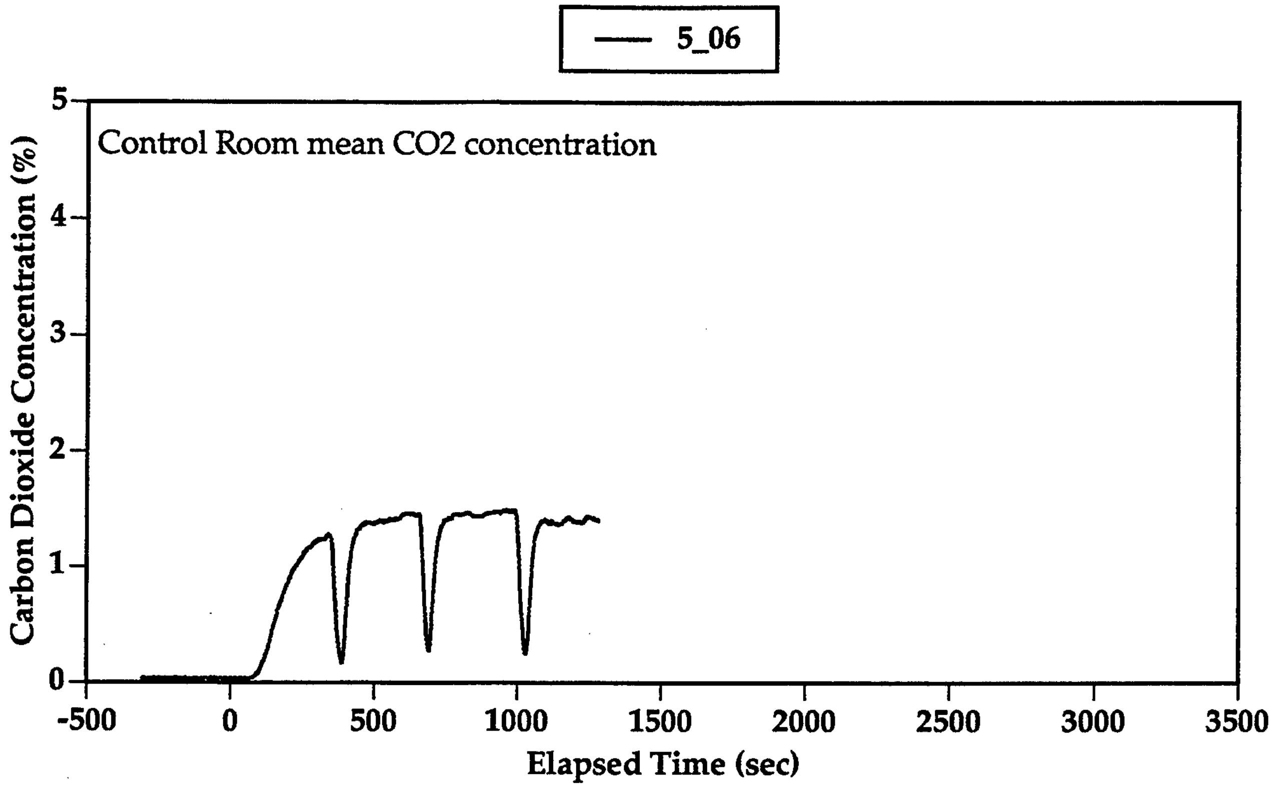
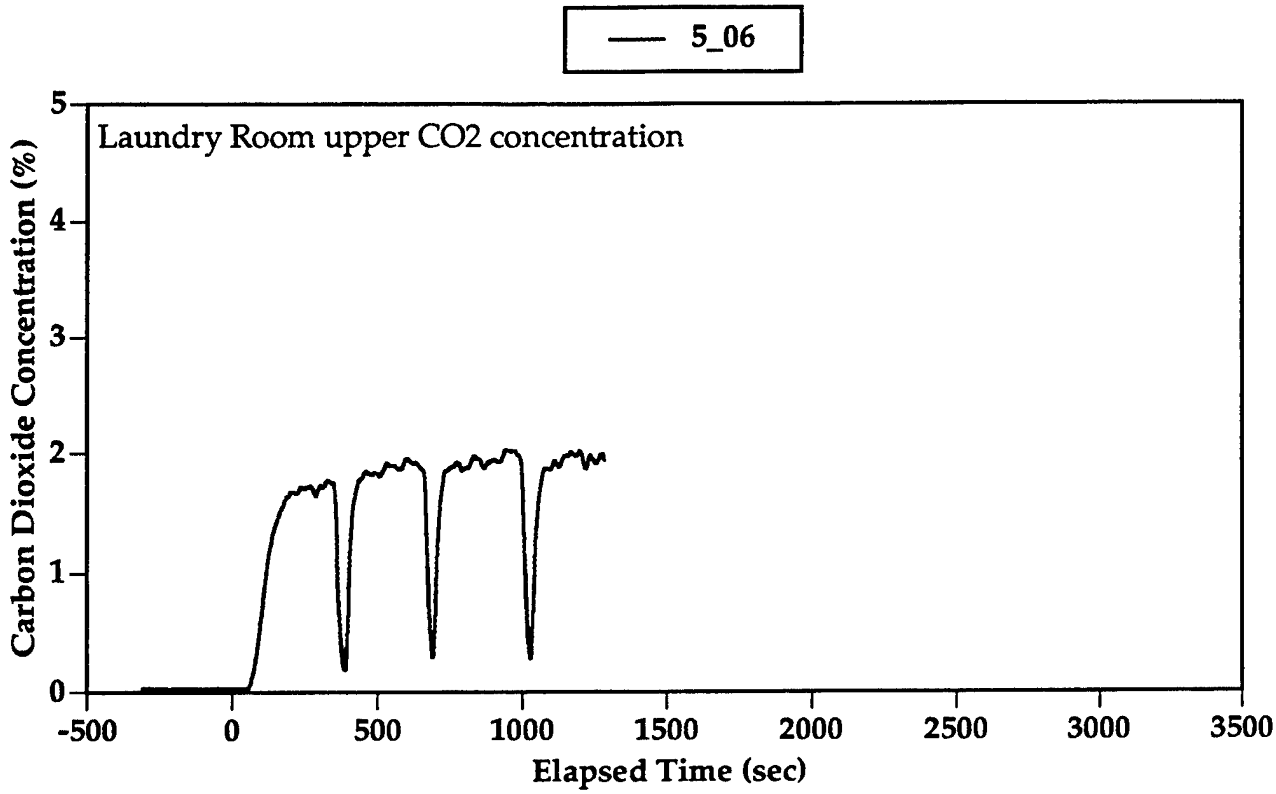


Figure B27. Mean carbon dioxide concentration in Control Room for Test 5_06. Spikes in the data occurred when the instrument was purged with air.



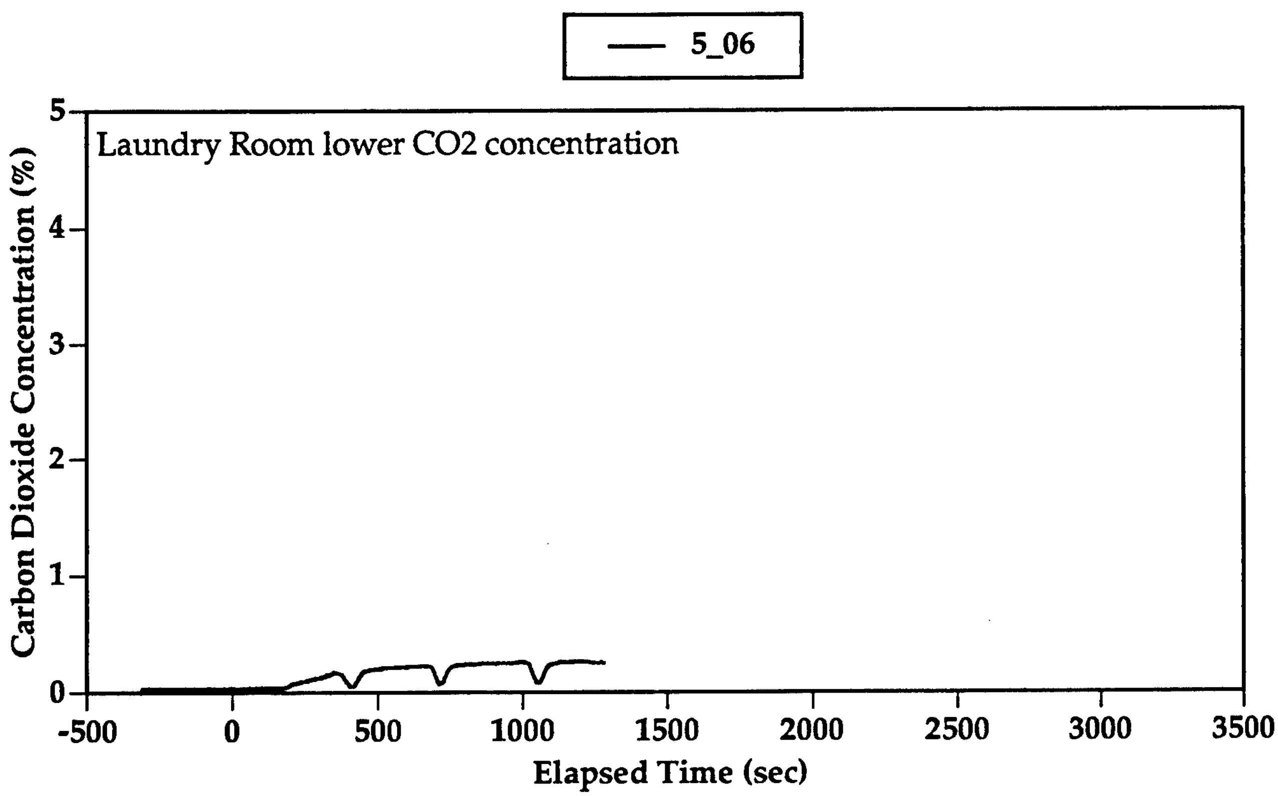


Figure B28. Upper and lower carbon dioxide concentrations in Laundry Room for Test 5_06. Spikes in the data occurred when the instrument was purged with air.

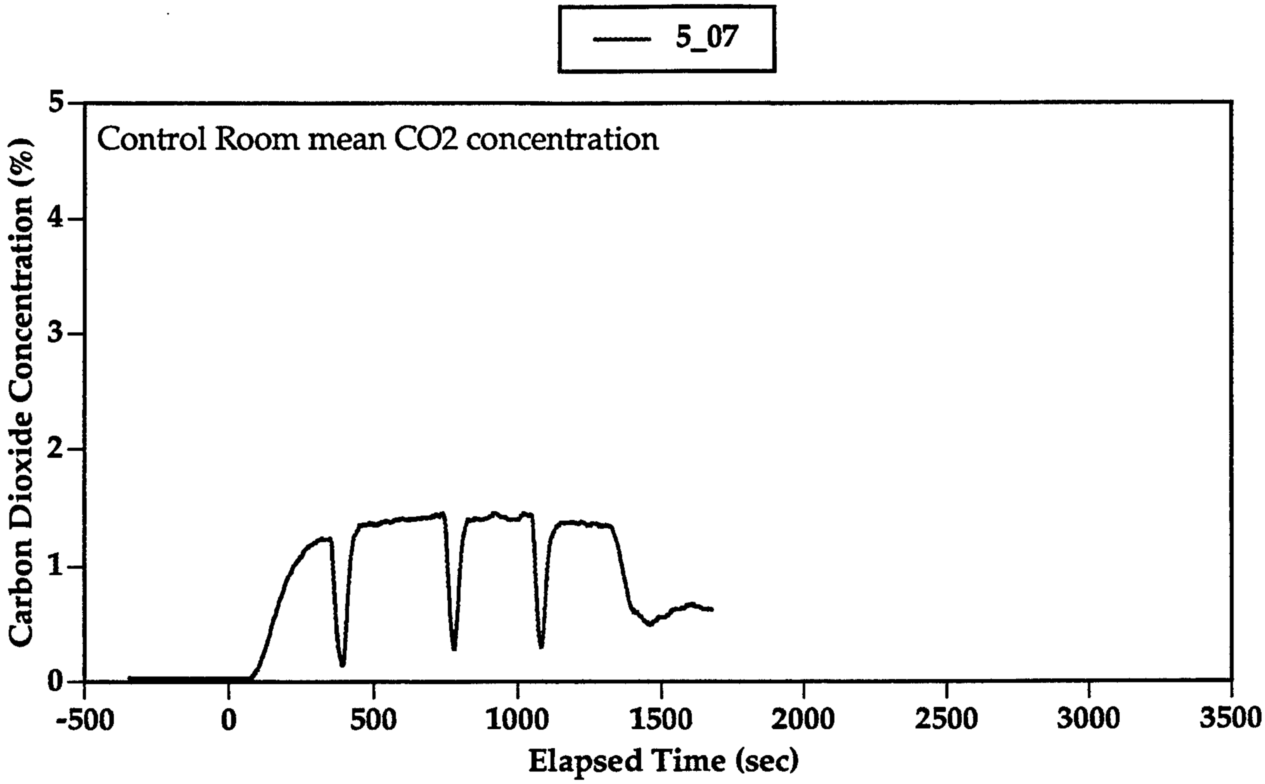
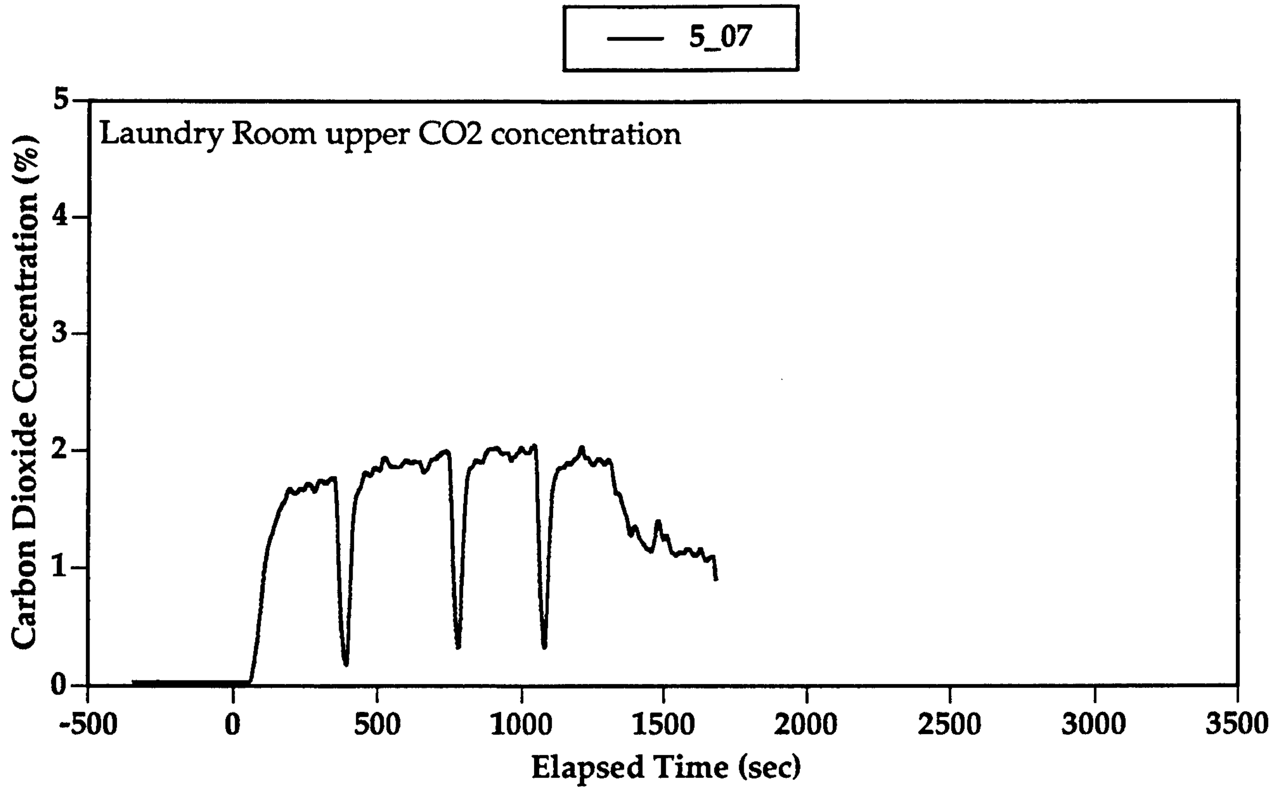


Figure B29. Mean carbon dioxide concentration in Control Room for Test 5_07. Spikes in the data occurred when the instrument was purged with air.



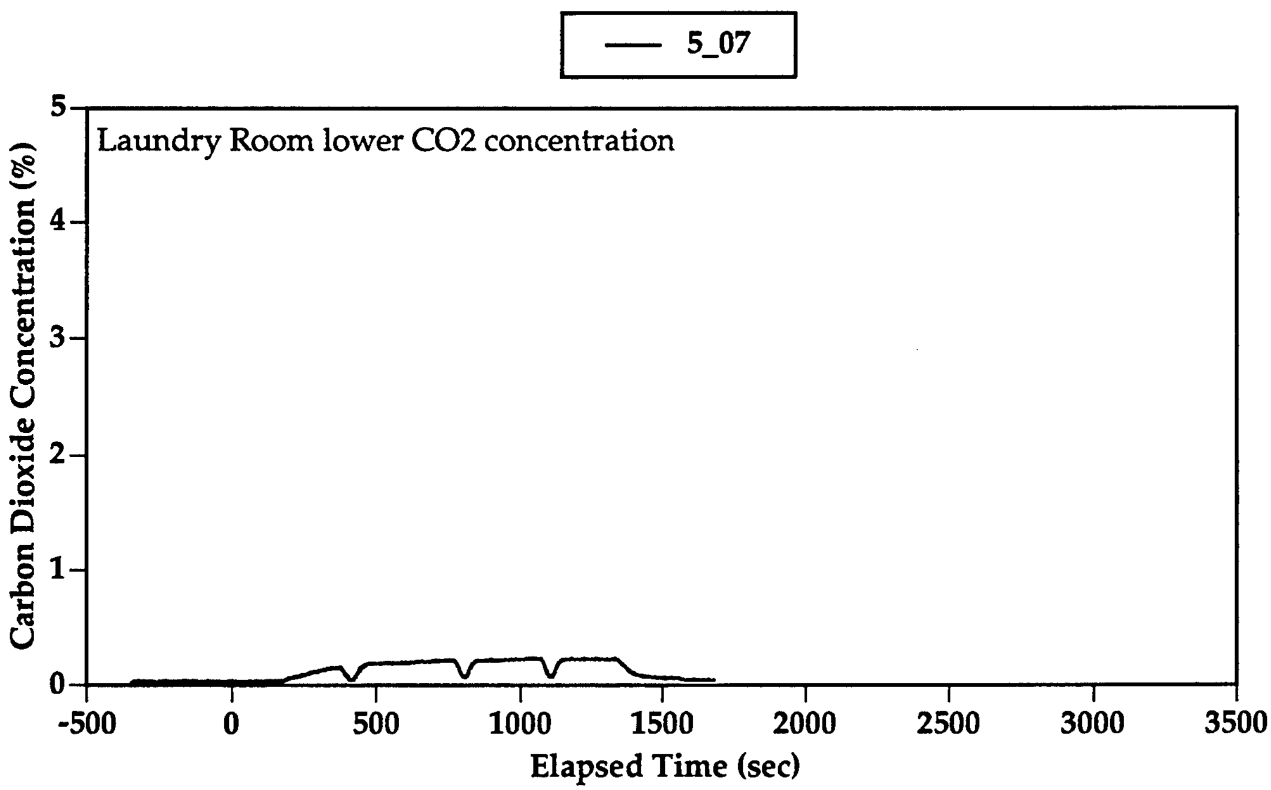


Figure B30. Upper and lower carbon dioxide concentrations in Laundry Room for Test 5_07. Spikes in the data occurred when the instrument was purged with air.

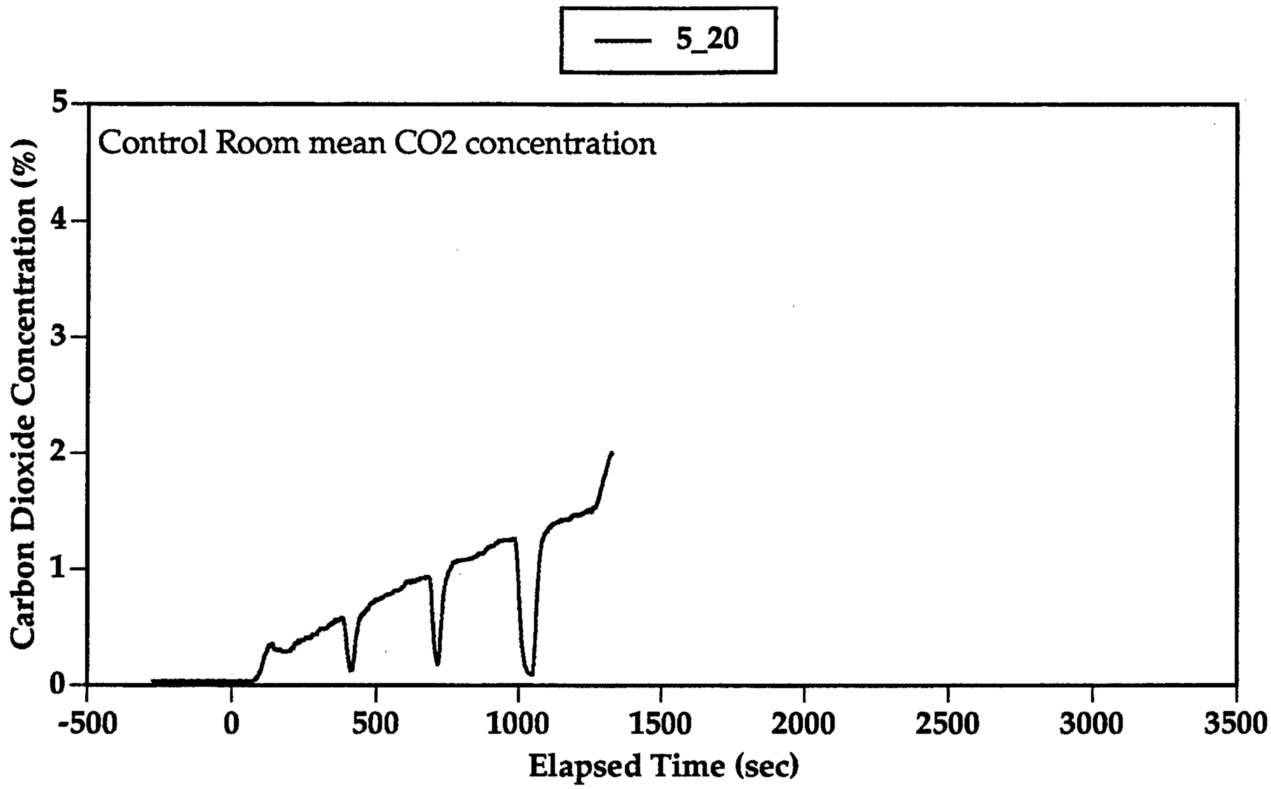
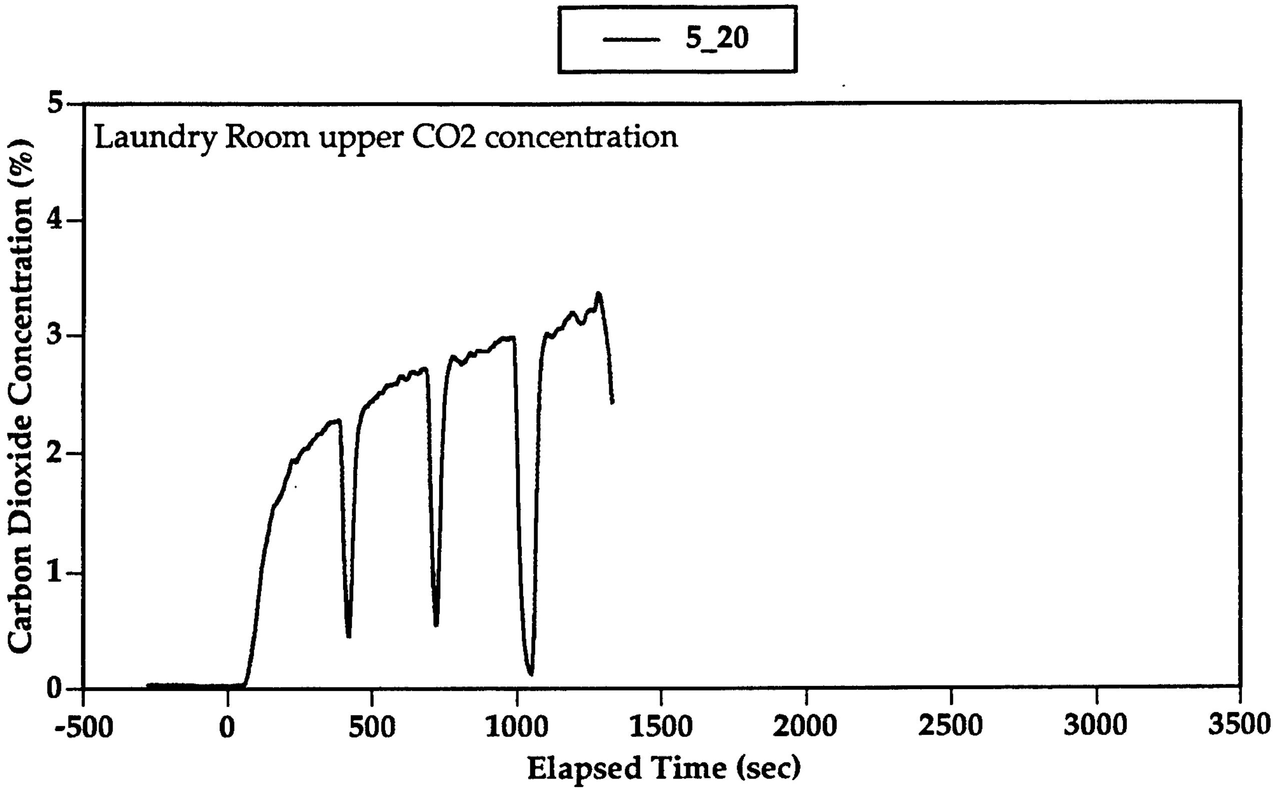


Figure B31. Mean carbon dioxide concentration in Control Room for Test 5_20. Spikes in the data occurred when the instrument was purged with air.



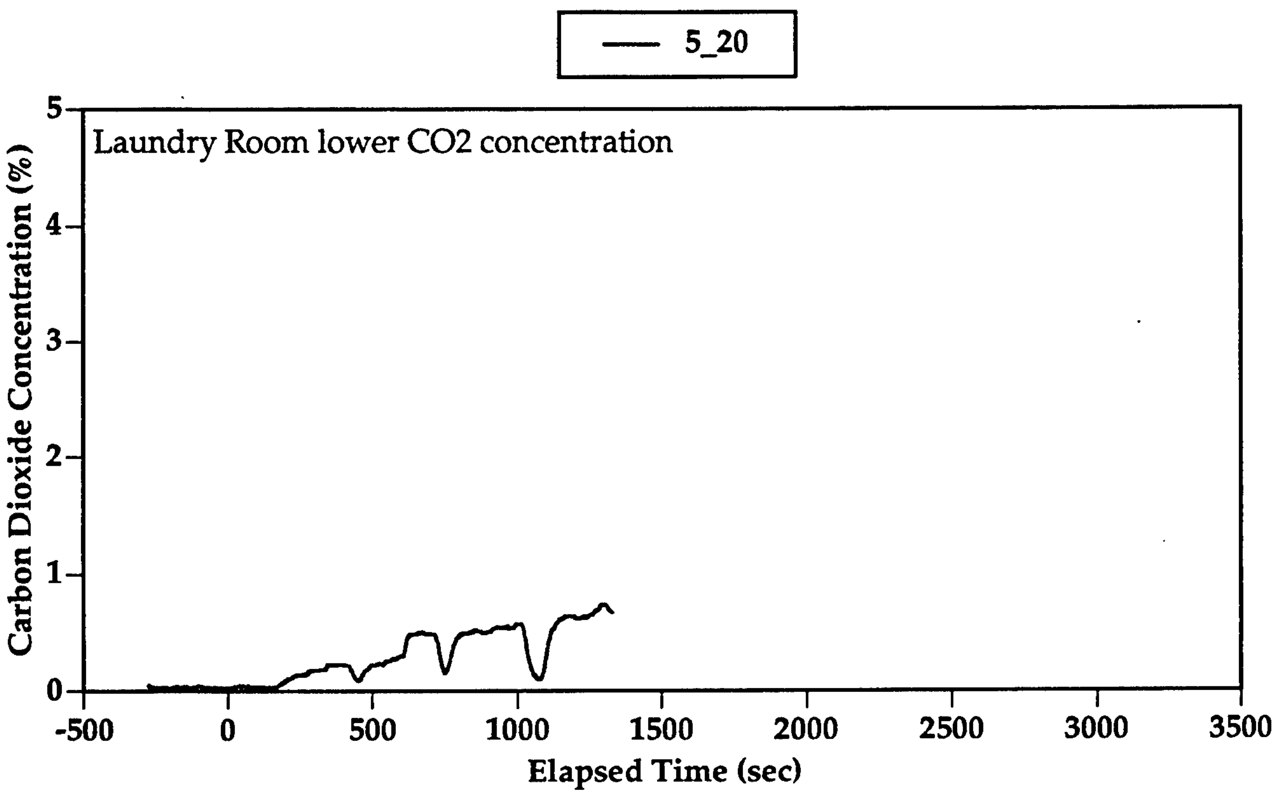


Figure B32. Upper and lower carbon dioxide concentrations in Laundry Room for Test 5_20. Spikes in the data occurred when the instrument was purged with air.

Chan	Sensor	Units	Cmpt	X	Y	Z	Dim. Units	Status
1.1				0	0	0		Invalid
2.1				0	0	0		Invalid
3.1				0	0	0		Invalid
4.1				0	0	0		Invalid
5.1				0	0	0		Invalid
6.1				0	0	0		Invalid
7.1				0	0	0		Invalid
8.1				0	0	0		Invalid
9.1				0	0	0		Invalid
10.1				0	0	0		Invalid
11.1				0	0	0		Invalid
12.1				0	0	0		Invalid
13.1				0	0	0		Invalid
14.1				0	0	0		Invalid
15.1				0	0	0		Invalid
16.1				0	0	0		Invalid
17.1				0	0	0		Invalid
18.1				0	0	0		Invalid
19.1				0	0	0		Invalid
20.1				0	0	0		Invalid
21.1				0	0	0		Invalid
22.1				0	0	0		Invalid
23.1				0	0	0		Invalid
24.1				0	0	0		Invalid
25.1				0	0	0		Invalid
26.1				0	0	0		Invalid
27.1				0	0	0		Invalid
28.1				0	0	0		Invalid
29.1				0	0	0		Invalid
30.1				0	0	0		Invalid
31.1				0	0	0		Invalid
32.1				0	0	0		Invalid
33.1				0	0	0		Invalid
34.1				0	0	0		Invalid
35.1				0	0	0		Invalid
36.1				0	0	0		Invalid
37.1				0	0	0		Invalid
38.1				0	0	0		Invalid

Table C - 1 Sensor configuration used for all tests in series 4. A sequence number has been appended to the channel number to specify which of the two dataloggers recorded the data. The sensor and units columns identify the type of instrument and the physical units of the data. The compartment, X, Y and Z columns locate the instrument by compartment name and coordinates within the compartment. In this work, X and Y were not used; Z was referenced to the compartment deck. Dimensional units specifies the units (meters or feet) used for X, Y and Z. Status is used internally by STAT - Invalid indicates that no configuration has been defined for the channel; Unchanged means that no changes have been made since the last time the channel configuration was saved.

Chan	Sensor	Units	Cmpt	X	Y	Z	Dim. Units	Status
39.1				0	0	0		Invalid
40.1				0	0	0		Invalid
41.1				0	0	0		Invalid
42.1				0	0	0		Invalid
43.1				0	0	0		Invalid
44.1				0	0	0		Invalid
45.1				0	0	0		Invalid
46.1				0	0	0		Invalid
47.1				0	0	0		Invalid
48.1				0	0	0		Invalid
49.1				0	0	0		Invalid
50.1				0	0	0		Invalid
51.1				0	0	0		Invalid
52.1				0	0	0		Invalid
53.1				0	0	0		Invalid
54.1				0	0	0		Invalid
55.1				0	0	0		Invalid
56.1				0	0	0		Invalid
57.1				0	0	0		Invalid
58.1				0	0	0		Invalid
59.1				0	0	0		Invalid
60.1	Air Thermocouple	Deg. C	Laundry Passageway	0	0	2.5	Meters	Unchanged
61.1	Air Thermocouple	Deg. C	Laundry Passageway	0	0	2	Meters	Unchanged
62.1	Air Thermocouple	Deg. C	Laundry Passageway	0	0	1.5	Meters	Unchanged
63.1	Air Thermocouple	Deg. C	Laundry Passageway	0	0	1	Meters	Unchanged
64.1	Air Thermocouple	Deg. C	Laundry Passageway	0	0	0.5	Meters	Unchanged
65.1	Air Thermocouple	Deg. C	Laundry Passageway	0	0	0.05	Meters	Unchanged
66.1	Air Thermocouple	Deg. C	Laundry Passageway	0	0	0	Meters	Unchanged
67.1	Air Thermocouple	Deg. C	Laundry Passageway	0	0	0	Meters	Unchanged
68.1				0	0	0		Invalid
69.1				0	0	0		Invalid
70.1				0	0	0		Invalid
71.1				0	0	0		Invalid
72.1				0	0	0		Invalid
73.1	Air Thermocouple	Deg. C	Control Room	0	0	2.5	Meters	Unchanged
74.1	Air Thermocouple	Deg. C	Control Room	0	0	2	Meters	Unchanged
75.1	Air Thermocouple	Deg. C	Control Room	0	0	1.5	Meters	Unchanged
76.1	Air Thermocouple	Deg. C	Control Room	0	0	1	Meters	Unchanged
77.1	Air Thermocouple	Deg. C	Control Room	0	0	0.5	Meters	Unchanged
78.1	Air Thermocouple	Deg. C	Nav. Equip.	0	0	2.5	Meters	Unchanged
79.1	Air Thermocouple	Deg. C	Nav. Equip.	0	0	2	Meters	Unchanged
80.1	Air Thermocouple	Deg. C	Nav. Equip.	0	0	1.5	Meters	Unchanged
81.1	Air Thermocouple	Deg. C	Nav. Equip.	0	0	1		Unchanged
82.1	Air Thermocouple	Deg. C	Nav. Equip.	0	0	0.5	Meters	Unchanged
83.1				0	0	0		Invalid
84.1				0	0	0		Invalid

Table C - 1 (Continued)

Chan	Sensor	Units	Cmpt	X	Y	Z	Dim. Units	Status
85.1				0	0	0		Invalid
86.1				0	0	0		Invalid
87.1				0	0	0		Invalid
88.1				0	0	0		Invalid
89.1				0	0	0		Invalid
90.1				0	0	0		Invalid
91.1				0	0	0		Invalid
92.1				0	0	0		Invalid
93.1				0	0	0		Invalid
94.1				0	0	0		Invalid
95.1				0	0	0		Invalid
96.1				0	0	0		Invalid
97.1				0	0	0		Invalid
98.1				0	0	0		Invalid
99.1				0	0	0		Invalid
100.1				0	0	0		Invalid
101.1				0	0	0		Invalid
102.1				0	0	0		Invalid
103.1				0	0	0		Invalid
104.1				0	0	0		Invalid
105.1				0	0	0		Invalid
106.1				0	0	0		Invalid
107.1				0	0	0		Invalid
108.1				0	0	0		Invalid
109.1				0	0	0		Invalid
110.1				0	0	0		Invalid
111.1				0	0	0		Invalid
112.1				0	0	0		Invalid
113.1				0	0	0		Invalid
114.1				0	0	0		Invalid
115.1				0	0	0		Invalid
116.1				0	0	0		Invalid
117.1				0	0	0		Invalid
118.1				0	0	0		Invalid
119.1				0	0	0		Invalid
120.1				0	0	0		Invalid
121.1				0	0	0		Invalid
122.1				0	0	0		Invalid
123.1				0	0	0		Invalid
124.1				0	0	0		Invalid
125.1				0	0	0		Invalid
126.1				0	0	0		Invalid
127.1				0	0	0		Invalid
128.1				0	0	0		Invalid
129.1	Air Thermocouple	Deg. C	Laundry	0	0	2.5	Meters	Unchanged

Table C - 1 (Continued)

Chan	Sensor	Units	Cmpt	X	Y	Z	Dim. Units	Status
130.1	Air Thermocouple	Deg. C	Laundry	0	0	2	Meters	Unchanged
131.1	Air Thermocouple	Deg. C	Laundry	0	0	1.5	Meters	Unchanged
132.1	Air Thermocouple	Deg. C	Laundry	0	0	1	Meters	Unchanged
133.1	Air Thermocouple	Deg. C	Laundry	0	0	0.5	Meters	Unchanged
134.1	Air Thermocouple	Deg. C	Laundry	0	0	0.05	Meters	Unchanged
135.1	Flame Thermocouple	Deg. C	Laundry	0	0	0	Meters	Unchanged
136.1	Flame Thermocouple	Deg. C	Laundry	0	0	0	Meters	Unchanged
137.1	Overhead Thermocouple	Deg. C	Laundry	0	0	2.56	Meters	Unchanged
138.1	Deck Thermocouple	Deg. C	Laundry	0	0	0	Meters	Unchanged
139.1				0	0	0		Invalid
140.1				0	0	0		Invalid
141.1				0	0	0		Invalid
142.1	Deck Thermocouple	Deg. C	Control Room	0	0	0	Meters	Unchanged
143.1	Bulkhead Thermocouple	Deg. C	Torpedo Room	0	0	1.5	Meters	Unchanged
144.1	Bulkhead Thermocouple	Deg. C	Laundry	0	0	1.5	Meters	Unchanged
165.1	Oxygen	%	Laundry	0	0	0		Unchanged
166.1	Oxygen	%	Control Room	0	0	0		Unchanged
167.1	Oxygen	%	Control Room	0	0	0		Unchanged
168.1	Oxygen	%	Laundry	0	0	0		Unchanged
169.1	Carbon Dioxide	%	Control Room	0	0	0		Unchanged
170.1	Carbon Dioxide	%	Control Room	0	0	0		Unchanged
171.1	Carbon Dioxide	%	Laundry	0	0	0		Unchanged
172.1	Carbon Dioxide	%	Laundry	0	0	0		Unchanged
173.1	Carbon Monoxide	%	Control Room	0	0	0		Unchanged
174.1	Carbon Monoxide	%	Control Room	0	0	0		Unchanged
175.1	Carbon Monoxide	%	Laundry	0	0	0		Unchanged
176.1	Carbon Monoxide	%	Laundry	0	0	0		Unchanged
189.1	Logic	Volts	Laundry	0	0	0		Unchanged
199.1				0	0	0		Invalid
200.1				0	0	0		Invalid
1.2				0	0	0		Invalid
2.2				0	0	0		Invalid
3.2				0	0	0		Invalid
4.2				0	0	0		Invalid
5.2				0	0	0		Invalid
6.2				0	0	0		Invalid
7.2				0	0	0		Invalid
8.2				0	0	0		Invalid
9.2				0	0	0		Invalid
10.2				0	0	0		Invalid
11.2				0	0	0		Invalid
12.2				0	0	0		Invalid
13.2				0	0	0		Invalid
14.2				0	0	0		Invalid
15.2				0	0	0		Invalid
16.2				0	0	0		Invalid

Table C - 1 (Continued)

Chan	Sensor	Units	Cmpt	X	Y	Z	Dim. Units	Status
17.2				0	0	0		Invalid
18.2				0	0	0		Invalid
19.2				0	0	0		Invalid
20.2				0	0	0		Invalid
21.2				0	0	0		Invalid
22.2				0	0	0		Invalid
23.2				0	0	0		Invalid
24.2				0	0	0		Invalid
25.2				0	0	0		Invalid
26.2				0	0	0		Invalid
27.2				0	0	0		Invalid
28.2				0	0	0		Invalid
29.2				0	0	0		Invalid
30.2				0	0	0		Invalid
31.2				0	0	0		Invalid
32.2				0	0	0		Invalid
33.2				0	0	0		Invalid
34.2				0	0	0		Invalid
35.2				0	0	0		Invalid
36.2				0	0	0		Invalid
37.2				0	0	0		Invalid
38.2				0	0	0		Invalid
39.2				0	0	0		Invalid
40.2				0	0	0		Invalid
41.2				0	0	0		Invalid
42.2				0	0	0		Invalid
43.2				0	0	0		Invalid
44.2	Optical Density	% Transmission	Control Room	0	0	2.43		Unchanged
45.2	Optical Density	% Transmission	Control Room	0	0	1.55		Unchanged
46.2	Optical Density	% Transmission	Control Room	0	0	0.69		Unchanged
47.2				0	0	0		Invalid
48.2				0	0	0		Invalid
49.2				0	0	0		Invalid
50.2				0	0	0		Invalid
51.2				0	0	0		Invalid
52.2				0	0	0		Invalid
53.2				0	0	0		Invalid
54.2				0	0	0		Invalid
55.2				0	0	0		Invalid
56.2				0	0	0		Invalid
57.2				0	0	0		Invalid
58.2				0	0	0		Invalid
59.2				0	0	0		Invalid
60.2				0	0	0		Invalid
61.2				0	0	0		Invalid
62.2				0	0	0		Invalid

Table C - 1 (Continued)

Chan	Sensor	Units	Cmpt	X	Y	Z	Dim. Units	Status
63.2				0	0	0		Invalid
64.2				0	0	0		Invalid
65.2				0	0	0		Invalid
66.2				0	0	0		Invalid
67.2				0	0	0		Invalid
68.2				0	0	0		Invalid
69.2				0	0	0		Invalid
85.2				0	0	0		Invalid
86.2				0	0	0		Invalid
87.2				0	0	0		Invalid
88.2				0	0	0		Invalid
89.2				0	0	0		Invalid
90.2				0	0	0		Invalid
91.2				0	0	0		Invalid
92.2				0	0	0		Invalid
93.2				0	0	0		Invalid
94.2				0	0	0		Invalid
95.2				0	0	0		Invalid
96.2				0	0	0		Invalid
97.2				0	0	0		Invalid
98.2				0	0	0		Invalid
99.2				0	0	0		Invalid
100.2				0	0	0		Invalid
101.2				0	0	0		Invalid
102.2				0	0	0		Invalid
103.2				0	0	0		Invalid
109.2				0	0	0		Invalid
110.2				0	0	0		Invalid
111.2				0	0	0		Invalid
112.2	Deck Thermocouple	Deg. C	Control Room	0	0	0	Meters	Unchanged
113.2	Air Thermocouple	Deg. C	Control Room	0	0	0.05	Meters	Unchanged
114.2	Deck Thermocouple	Deg. C	Nav. Equip.	0	0	0	Meters	Unchanged
115.2	Air Thermocouple	Deg. C	Nav. Equip.	0	0	0.05	Meters	Unchanged
116.2				0	0	0		Invalid
117.2				0	0	0		Invalid
118.2	Deck Thermocouple	Deg. C	unknown	0	0	0	Meters	Unchanged
119.2	Air Thermocouple	Deg. C	unknown	0	0	0.05	Meters	Unchanged
120.2	Deck Thermocouple	Deg. C	Control Room	0	0	0	Meters	Unchanged
121.2	Air Thermocouple	Deg. C	Control Room	0	0	0.05	Meters	Unchanged
122.2				0	0	0		Invalid
123.2				0	0	0		Invalid
124.2	Air Thermocouple	Deg. C	Control Room	0	0	2.5	Meters	Unchanged
125.2	Air Thermocouple	Deg. C	Control Room	0	0	2	Meters	Unchanged
126.2	Air Thermocouple	Deg. C	Control Room	0	0	1.5	Meters	Unchanged
127.2	Air Thermocouple	Deg. C	Control Room	0	0	1	Meters	Unchanged
128.2	Air Thermocouple	Deg. C	Control Room	0	0	0.5	Meters	Unchanged

Table C - 1 (Continued)

Chan	Sensor	Units	Cmpt	X	Y	Z	Dim. Units	Status
129.2	Air Thermocouple	Deg. C	Control Room	0	0	0.05	Meters	Unchanged
130.2				0	0	0		Invalid
131.2				0	0	0		Invalid
132.2				0	0	0		Invalid
133.2				0	0	0		Invalid
134.2				0	0	0		Invalid
135.2				0	0	0		Invalid
136.2				0	0	0		Invalid
137.2				0	0	0		Invalid
138.2				0	0	0		Invalid
139.2				0	0	0		Invalid
140.2				0	0	0		Invalid
141.2				0	0	0		Invalid
142.2				0	0	0		Invalid
143.2				0	0	0		Invalid
144.2				0	0	0		Invalid
145.2				0	0	0		Invalid
146.2				0	0	0		Invalid
147.2				0	0	0		Invalid
148.2				0	0	0		Invalid
149.2				0	0	0		Invalid
150.2				0	0	0		Invalid
151.2				0	0	0		Invalid
152.2				0	0	0		Invalid
153.2				0	0	0		Invalid
154.2				0	0	0		Invalid
155.2				0	0	0		Invalid
156.2				0	0	0		Invalid
159.2				0	0	0		Invalid
160.2				0	0	0		Invalid
161.2				0	0	0		Invalid
162.2				0	0	0		Invalid
163.2				0	0	0		Invalid
164.2				0	0	0		Invalid
165.2				0	0	0		Invalid
166.2				0	0	0		Invalid
167.2				0	0	0		Invalid
168.2				0	0	0		Invalid
169.2				0	0	0		Invalid
170.2				0	0	0		Invalid
171.2				0	0	0		Invalid
172.2				0	0	0		Invalid
173.2				0	0	0		Invalid
174.2				0	0	0		Invalid
175.2				0	0	0		Invalid
176.2				0	0	0		Invalid

Table C - 1 (Continued)

Chan	Sensor	Units	Cmpt	X	Y	Z	Dim. Units	Status
177.2				0	0	0		Invalid
178.2				0	0	0		Invalid
180.2				0	0	0		Invalid
181.2				0	0	0		Invalid
182.2				0	0	0		Invalid
183.2	Radiometer	BTU/ft2/sec	Laundry	0	0	0		Unchanged
184.2	Calorimeter	BTU/ft2/sec	Laundry	0	0	0		Unchanged
185.2	Optical Density	% Transmission	Laundry Passageway	0	0	2.5	Meters	Unchanged
186.2	Optical Density	% Transmission	Laundry Passageway	0	0	1.5	Meters	Unchanged
187.2	Optical Density	% Transmission	Laundry Passageway	0	0	0.5	Meters	Unchanged
188.2				0	0	0		Invalid
189.2				0	0	0		Invalid
190.2				0	0	0		Invalid

Table C - 1 (Continued)

Chan	Sensor	Units	Cmpt	X	Y	Z	Dim. Units	Status
1.1				0	0	0		Invalid
2.1				0	0	0		Invalid
3.1				0	0	0		Invalid
4.1				0	0	0		Invalid
5.1				0	0	0		Invalid
6.1				0	0	0		Invalid
7.1				0	0	0		Invalid
8.1				0	0	0		Invalid
9.1				0	0	0		Invalid
10.1				0	0	0		Invalid
11.1				0	0	0		Invalid
12.1				0	0	0		Invalid
13.1				0	0	0		Invalid
14.1				0	0	0		Invalid
15.1				0	0	0		Invalid
16.1				0	0	0		Invalid
17.1				0	0	0		Invalid
18.1				0	0	0		Invalid
19.1				0	0	0		Invalid
20.1				0	0	0		Invalid
21.1				0	0	0		Invalid
22.1				0	0	0		Invalid
23.1				0	0	0		Invalid
24.1				0	0	0		Invalid
25.1				0	0	0		Invalid
26.1				0	0	0		Invalid
27.1				0	0	0		Invalid
28.1				0	0	0		Invalid
29.1				0	0	0		Invalid
30.1				0	0	0		Invalid
31.1				0	0	0		Invalid
32.1				0	0	0		Invalid
33.1				0	0	0		Invalid
34.1				0	0	0		Invalid
35.1				0	0	0		Invalid
36.1				0	0	0		Invalid
37.1				0	0	0		Invalid
38.1				0	0	0		Invalid
39.1				0	0	0		Invalid
40.1				0	0	0		Invalid
41.1				0	0	0		Invalid
42.1				0	0	0		Invalid
43.1				0	0	0		Invalid
44.1				0	0	0		Invalid
45.1				0	0	0		Invalid

Table C - 2 Sensor configuration used for all tests in series 5. A sequence number has been appended to the channel number to specify which of the two dataloggers recorded the data. The sensor and units columns identify the type of instrument and the physical units of the data. The compartment, X, Y and Z columns locate the instrument by compartment name and coordinates within the compartment. In this work, X and Y were not used; Z was referenced to the compartment deck. Dimensional units specifies the units (meters or feet) used for X, Y and Z. Status is used internally by STAT - Invalid indicates that no configuration has been defined for the channel; Unchanged means that no changes have been made since the last time the channel configuration was saved.

Chan	Sensor	Units	Cmpt	X	Y	Z	Dim. Units	Status
46.1				0	0	0		Invalid
47.1				0	0	0		Invalid
48.1				0	0	0		Invalid
49.1				0	0	0		Invalid
50.1				0	0	0		Invalid
51.1				0	0	0		Invalid
52.1				0	0	0		Invalid
53.1				0	0	0		Invalid
54.1				0	0	0		Invalid
55.1				0	0	0		Invalid
56.1				0	0	0		Invalid
57.1				0	0	0		Invalid
58.1				0	0	0		Invalid
59.1				0	0	0		Invalid
60.1	Air Thermocouple	Deg. C	Laundry Passageway	0	0	2.5	Meters	Unchanged
61.1	Air Thermocouple	Deg. C	Laundry Passageway	0	0	2	Meters	Unchanged
62.1	Air Thermocouple	Deg. C	Laundry Passageway	0	0	1.5	Meters	Unchanged
63.1	Air Thermocouple	Deg. C	Laundry Passageway	0	0	1	Meters	Unchanged
64.1	Air Thermocouple	Deg. C	Laundry Passageway	0	0	0.5	Meters	Unchanged
65.1	Air Thermocouple	Deg. C	Laundry Passageway	0	0	0.05	Meters	Unchanged
66.1	Air Thermocouple	Deg. C	Laundry Passageway	0	0	0	Meters	Unchanged
67.1	Air Thermocouple	Deg. C	Laundry Passageway	0	0	0	Meters	Unchanged
68.1				0	0	0		Invalid
69.1				0	0	0		Invalid
70.1				0	0	0		Invalid
71.1				0	0	0		Invalid
72.1				0	0	0		Invalid
73.1	Air Thermocouple	Deg. C	Control Room	0	0	2.5	Meters	Unchanged
74.1	Air Thermocouple	Deg. C	Control Room	0	0	2	Meters	Unchanged
75.1	Air Thermocouple	Deg. C	Control Room	0	0	1.5	Meters	Unchanged
76.1	Air Thermocouple	Deg. C	Control Room	0	0	1	Meters	Unchanged
77.1	Air Thermocouple	Deg. C	Control Room	0	0	0.5	Meters	Unchanged
78.1	Air Thermocouple	Deg. C	Nav. Equip.	0	0	2.5	Meters	Unchanged
79.1	Air Thermocouple	Deg. C	Nav. Equip.	0	0	2	Meters	Unchanged
80.1	Air Thermocouple	Deg. C	Nav. Equip.	0	0	1.5	Meters	Unchanged
81.1	Air Thermocouple	Deg. C	Nav. Equip.	0	0	1	Meters	Unchanged
82.1	Air Thermocouple	Deg. C	Nav. Equip.	0	0	0.5	Meters	Unchanged
83.1				0	0	0		Invalid
84.1				0	0	0		Invalid
85.1				0	0	0		Invalid
86.1				0	0	0		Invalid
87.1				0	0	0		Invalid
88.1				0	0	0		Invalid
89.1				0	0	0		Invalid
90.1				0	0	0		Invalid
91.1				0	0	0		Invalid
92.1				0	0	0		Invalid
93.1				0	0	0		Invalid
94.1				0	0	0		Invalid
95.1				0	0	0		Invalid
96.1				0	0	0		Invalid
97.1				0	0	0		Invalid

Table C - 2 (Continued)

Chan	Sensor	Units	Cmpt	X	Y	Z	Dim. Units	Status
98.1				0	0	0		Invalid
99.1				0	0	0		Invalid
100.1				0	0	0		Invalid
101.1				0	0	0		Invalid
102.1				0	0	0		Invalid
103.1				0	0	0		Invalid
104.1				0	0	0		Invalid
105.1				0	0	0		Invalid
106.1				0	0	0		Invalid
107.1				0	0	0		Invalid
108.1				0	0	0		Invalid
109.1				0	0	0		Invalid
110.1				0	0	0		Invalid
111.1				0	0	0		Invalid
112.1				0	0	0		Invalid
113.1				0	0	0		Invalid
114.1				0	0	0		Invalid
115.1				0	0	0		Invalid
116.1				0	0	0		Invalid
117.1				0	0	0		Invalid
118.1				0	0	0		Invalid
119.1				0	0	0		Invalid
120.1				0	0	0		Invalid
121.1				0	0	0		Invalid
122.1				0	0	0		Invalid
123.1				0	0	0		Invalid
124.1				0	0	0		Invalid
125.1				0	0	0		Invalid
126.1				0	0	0		Invalid
127.1				0	0	0		Invalid
128.1				0	0	0		Invalid
129.1	Air Thermocouple	Deg. C	Laundry	0	0	2.5	Meters	Unchanged
130.1	Air Thermocouple	Deg. C	Laundry	0	0	2	Meters	Unchanged
131.1	Air Thermocouple	Deg. C	Laundry	0	0	1.5	Meters	Unchanged
132.1	Air Thermocouple	Deg. C	Laundry	0	0	1	Meters	Unchanged
133.1	Air Thermocouple	Deg. C	Laundry	0	0	0.5	Meters	Unchanged
134.1	Air Thermocouple	Deg. C	Laundry	0	0	0.05	Meters	Unchanged
135.1	Flame Thermocouple	Deg. C	Laundry	0	0	0	Meters	Unchanged
136.1	Flame Thermocouple	Deg. C	Laundry	0	0	0	Meters	Unchanged
137.1	Overhead Thermocouple	Deg. C	Laundry	0	0	2.56	Meters	Unchanged
138.1	Deck Thermocouple	Deg. C	Laundry	0	0	0	Meters	Unchanged
139.1				0	0	0		Invalid
140.1				0	0	0		Invalid
141.1				0	0	0		Invalid
142.1	Deck Thermocouple	Deg. C	Control Room	0	0	0	Meters	Unchanged
143.1	Bulkhead Thermocouple	Deg. C	Torpedo Room	0	0	1.5	Meters	Unchanged
144.1	Bulkhead Thermocouple	Deg. C	Laundry	0	0	1.5	Meters	Unchanged
161.1	Oxygen	%	Control Room	0	0	0	Meters	Unchanged
162.1	Oxygen	%	Control Room	0	0	0	Meters	Unchanged

Table C - 2 (Continued)

Chan	Sensor	Units	Cmpt	X	Y	Z	Dim. Units	Status
163.1	Oxygen	%	Laundry	0	0	0	Meters	Unchanged
164.1	Oxygen	%	Laundry	0	0	0	Meters	Unchanged
165.1	Carbon Dioxide	%	Control Room	0	0	0	Meters	Unchanged
166.1	Carbon Dioxide	%	Control Room	0	0	0	Meters	Unchanged
167.1	Carbon Dioxide	%	Laundry	0	0	0	Meters	Unchanged
168.1	Carbon Dioxide	%	Laundry	0	0	0	Meters	Unchanged
169.1	Carbon Monoxide	%	Control Room	0	0	0	Meters	Unchanged
170.1	Carbon Monoxide	%	Control Room	0	0	0	Meters	Unchanged
171.1	Carbon Monoxide	%	Laundry	0	0	0	Meters	Unchanged
172.1	Carbon Monoxide	%	Laundry	0	0	0	Meters	Unchanged
189.1	Logic	Volts	Laundry	0	0	0		Unchanged
199.1				0	0	0		Invalid
200.1				0	0	0		Invalid
1.2				0	0	0		Invalid
2.2				0	0	0		Invalid
3.2				0	0	0		Invalid
4.2				0	0	0		Invalid
5.2				0	0	0		Invalid
6.2				0	0	0		Invalid
7.2				0	0	0		Invalid
8.2				0	0	0		Invalid
9.2				0	0	0		Invalid
10.2				0	0	0		Invalid
11.2				0	0	0		Invalid
12.2				0	0	0		Invalid
13.2				0	0	0		Invalid
14.2				0	0	0		Invalid
15.2				0	0	0		Invalid
16.2				0	0	0		Invalid
17.2				0	0	0		Invalid
18.2				0	0	0		Invalid
19.2				0	0	0		Invalid
20.2				0	0	0		Invalid
21.2				0	0	0		Invalid
22.2				0	0	0		Invalid
23.2				0	0	0		Invalid
24.2				0	0	0		Invalid
25.2				0	0	0		Invalid
26.2				0	0	0		Invalid
27.2				0	0	0		Invalid
28.2				0	0	0		Invalid
29.2				0	0	0		Invalid
30.2				0	0	0		Invalid
31.2				0	0	0		Invalid
32.2				0	0	0		Invalid
33.2				0	0	0		Invalid
34.2				0	0	0		Invalid
35.2				0	0	0		Invalid
36.2				0	0	0		Invalid
37.2				0	0	0		Invalid
38.2				0	0	0		Invalid
39.2				0	0	0		Invalid
40.2				0	0	0		Invalid
41.2				0	0	0		Invalid

Table C - 2 (Continued)

Chan	Sensor	Units	Cmpt	X	Y	Z	Dim. Units	Status
42.2				0	0	0		Invalid
43.2				0	0	0		Invalid
44.2	Optical Density	% Transmission	Control Room	0	0	2.43	Meters	Unchanged
45.2	Optical Density	% Transmission	Control Room	0	0	1.55	Meters	Unchanged
46.2	Optical Density	% Transmission	Control Room	0	0	0.69	Meters	Unchanged
47.2				0	0	0		Invalid
48.2				0	0	0		Invalid
49.2				0	0	0		Invalid
50.2				0	0	0		Invalid
51.2				0	0	0		Invalid
52.2				0	0	0		Invalid
53.2				0	0	0		Invalid
54.2				0	0	0		Invalid
55.2				0	0	0		Invalid
56.2				0	0	0		Invalid
57.2				0	0	0		Invalid
58.2				0	0	0		Invalid
59.2				0	0	0		Invalid
60.2				0	0	0		Invalid
61.2				0	0	0		Invalid
62.2				0	0	0		Invalid
63.2				0	0	0		Invalid
64.2				0	0	0		Invalid
65.2				0	0	0		Invalid
66.2				0	0	0		Invalid
67.2				0	0	0		Invalid
68.2				0	0	0		Invalid
69.2				0	0	0		Invalid
85.2				0	0	0		Invalid
86.2				0	0	0		Invalid
87.2				0	0	0		Invalid
88.2				0	0	0		Invalid
89.2				0	0	0		Invalid
90.2				0	0	0		Invalid
91.2				0	0	0		Invalid
92.2				0	0	0		Invalid
93.2				0	0	0		Invalid
94.2				0	0	0		Invalid
95.2				0	0	0		Invalid
96.2				0	0	0		Invalid
97.2				0	0	0		Invalid
98.2				0	0	0		Invalid
99.2				0	0	0		Invalid
100.2				0	0	0		Invalid
101.2				0	0	0		Invalid
102.2				0	0	0		Invalid
103.2				0	0	0		Invalid
109.2				0	0	0		Invalid
110.2				0	0	0		Invalid
111.2				0	0	0		Invalid
112.2	Deck Thermocouple	Deg. C	Control Room	0	0	0	Meters	Unchanged
113.2	Air Thermocouple	Deg. C	Control Room	0	0	0.05	Meters	Unchanged
114.2	Deck Thermocouple	Deg. C	Nav. Equip.	0	0	0	Meters	Unchanged
115.2	Air Thermocouple	Deg. C	Nav. Equip.	0	0	0.05	Meters	Unchanged

Table C - 2 (Continued)

Chan	Sensor	Units	Cmpt	X	Y	Z	Dim. Units	Status
116.2				0	0	0		Invalid
117.2				0	0	0		Invalid
118.2	Deck Thermocouple	Deg. C	unknown	0	0	0	Meters	Unchanged
119.2	Air Thermocouple	Deg. C	unknown	0	0	0.05	Meters	Unchanged
120.2	Deck Thermocouple	Deg. C	Control Room	0	0	0	Meters	Unchanged
121.2	Air Thermocouple	Deg. C	Control Room	0	0	0.05	Meters	Unchanged
122.2				0	0	0		Invalid
123.2				0	0	0		Invalid
124.2	Air Thermocouple	Deg. C	Control Room	0	0	2.5	Meters	Unchanged
125.2	Air Thermocouple	Deg. C	Control Room	0	0	2	Meters	Unchanged
126.2	Air Thermocouple	Deg. C	Control Room	0	0	1.5	Meters	Unchanged
127.2	Air Thermocouple	Deg. C	Control Room	0	0	1	Meters	Unchanged
128.2	Air Thermocouple	Deg. C	Control Room	0	0	0.5	Meters	Unchanged
129.2	Air Thermocouple	Deg. C	Control Room	0	0	0.05	Meters	Unchanged
130.2				0	0	0		Invalid
131.2				0	0	0		Invalid
132.2				0	0	0		Invalid
133.2				0	0	0		Invalid
134.2				0	0	0		Invalid
135.2				0	0	0		Invalid
136.2				0	0	0		Invalid
137.2				0	0	0		Invalid
138.2				0	0	0		Invalid
139.2				0	0	0		Invalid
140.2				0	0	0		Invalid
141.2				0	0	0		Invalid
142.2				0	0	0		Invalid
143.2				0	0	0		Invalid
144.2				0	0	0		Invalid
145.2				0	0	0		Invalid
146.2				0	0	0		Invalid
147.2				0	0	0		Invalid
148.2				0	0	0		Invalid
149.2				0	0	0		Invalid
150.2				0	0	0		Invalid
152.2				0	0	0		Invalid
153.2				0	0	0		Invalid
154.2				0	0	0		Invalid
155.2				0	0	0		Invalid
156.2				0	0	0		Invalid
159.2				0	0	0		Invalid
160.2				0	0	0		Invalid
161.2				0	0	0		Invalid
162.2				0	0	0		Invalid
163.2				0	0	0		Invalid
164.2				0	0	0		Invalid
165.2				0	0	0		Invalid
166.2				0	0	0		Invalid
167.2				0	0	0		Invalid
168.2				0	0	0		Invalid
169.2				0	0	0		Invalid
170.2				0	0	0		Invalid
171.2				0	0	0		Invalid
172.2				0	0	0		Invalid

Table C - 2 (Continued)

Chan	Sensor	Units	Cmpt	X	Y	Z	Dim. Units	Status
174.2				0	0	0		Invalid
175.2				0	0	0		Invalid
176.2				0	0	0		Invalid
177.2				0	0	0		Invalid
178.2				0	0	0		Invalid
179.2				0	0	0		Invalid
180.2				0	0	0		Invalid
181.2				0	0	0		Invalid
182.2				0	0	0		Invalid
183.2	Radiometer	kW/m^2	Laundry	0	0	1	Meters	Unchanged
184.2	Calorimeter	kW/m^2	Laundry	0	0	1	Meters	Unchanged
185.2	Optical Density	% Transmission	Laundry Passageway	0	0	2.5	Meters	Unchanged
186.2	Optical Density	% Transmission	Laundry Passageway	0	0	1.5	Meters	Unchanged
187.2	Optical Density	% Transmission	Laundry Passageway	0	0	0.5	Meters	Unchanged
188.2				0	0	0		Invalid
189.2				0	0	0		Invalid
190.2				0	0	0		Invalid
191.2				0	0	0		Invalid
193.2				0	0	0		Invalid

Table C - 2 (Continued)